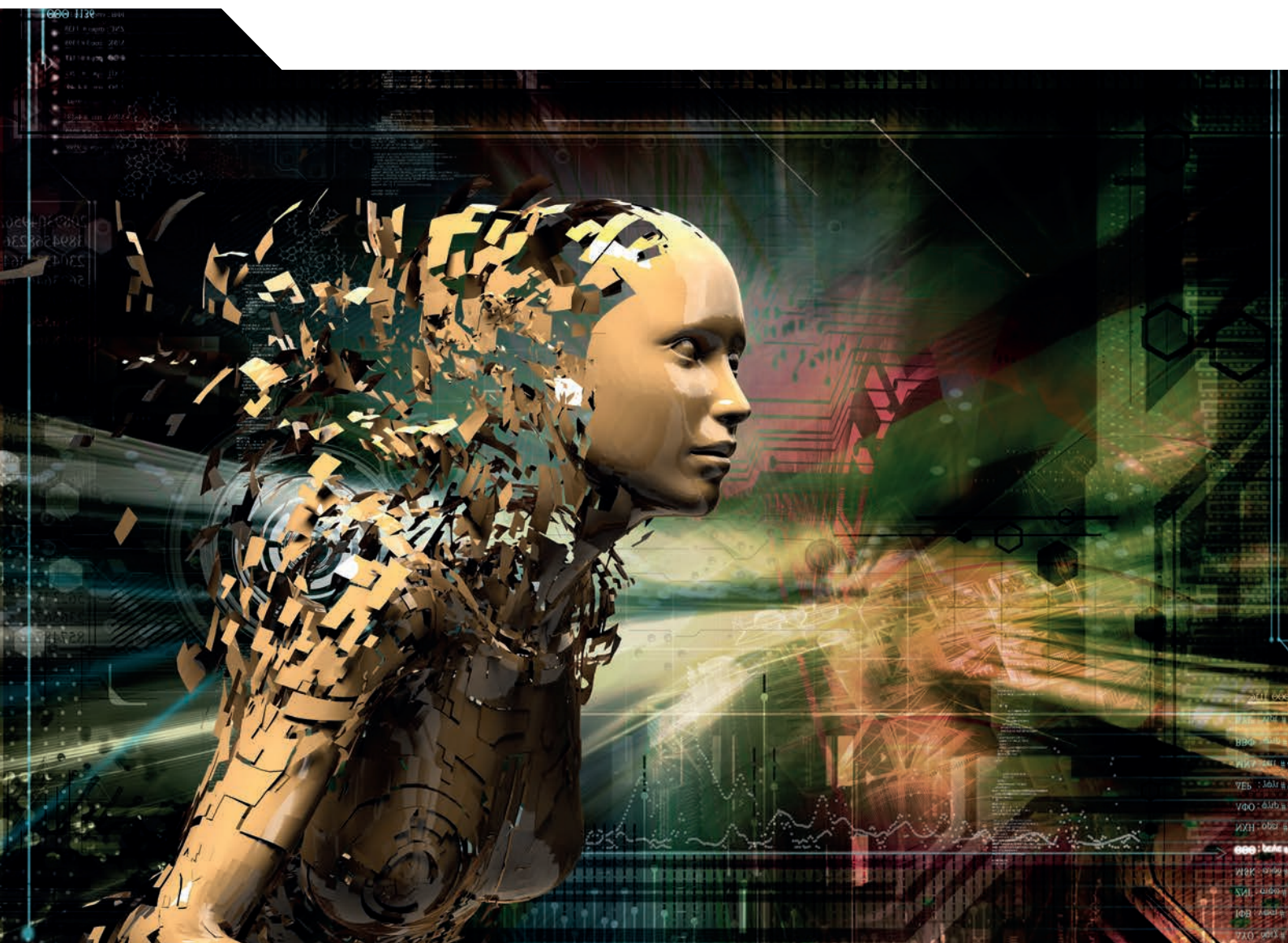




Digital Innovation

SEIZING POLICY OPPORTUNITIES



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Foreword

The report discusses the main findings of the 2017-18 OECD *Digital and Open Innovation project*. The project was conducted by the OECD Working Party on Innovation and Technology Policy (TIP) to help innovation policy makers identify priority areas for innovation policy action and reform, so as to promote innovation and inclusive, sustainable growth in the new digital age.

In order to help inform policy, this report outlines how innovation is changed by the digital transformation, and features a comprehensive discussion on all the innovation policy domains that need adjustments. In some of these domains, particularly in the field of data access policies, the way forward is still very much in debate. Policy examples from case studies conducted in the course of the project shed light on specific best practices.

The report also builds on and contributes to the OECD-wide *Going Digital* project (www.oecd.org/going-digital/).

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Reader's guide

This short report presents a synthesis of the main outcomes of the OECD TIP Working Party's *Digital and Open Innovation* project (2017-18). It targets in particular policy makers, and contains the project's main findings and policy recommendations. The report is part of a broad range of materials produced in the course of the project – including three policy papers, a number of country case studies and contributions, and four brochures summarising the discussions of each of the project workshops.

In particular, the following policy papers on various aspects of digital innovation form the basis for discussions and conclusions presented in this report:

- “Innovation policies in the digital age” discusses how digitalisation is transforming innovation processes and outcomes, and explores the ways in which innovation policy needs to adapt in order to respond to new challenges. The paper also discusses the economy-wide effects of digital innovation in terms of business dynamics, market structures and distribution (Guellec and Paunov, 2018). This paper expands on the issues discussed in Chapters 1 and 3.
- “The impacts of digital transformation on innovation across sectors” discusses the similarities and differences in how the digital transformation affects innovation processes and outcomes in different sectors. It focuses on three sectors of economic activity: agri-food, automotive/transportation, and retail (Paunov and Planes-Satorra, 2019). This paper expands on the issues discussed in Chapter 2.
- “The digital innovation policy landscape in 2019” provides an overview of policy strategies and initiatives recently adopted in a number of OECD countries to support digital transformation. Initiatives focus on i) enhancing digital technology diffusion and adoption; ii) promoting digital entrepreneurship; and iii) supporting research and innovation in key sectors/technologies (Planes-Satorra and Paunov, 2019). This paper expands on the issues discussed in Chapter 4.

The report also builds on a number of country case study contributions to the TIP Working Party's *Digital and Open Innovation* project. Such case studies include eight policy case studies – each focusing on a new innovation policy initiative for the digital transformation – and three sectoral case studies – exploring the impacts of digital transformation on specific sectors or firms (Tables RG1 and RG2). Additional country contributions – such as summaries of recent studies on digital technology adoption trends, and information on new initiatives related to the digital transformation – have also enriched the report. These case studies and additional contributions will be made available in a dedicated webpage.

Table RG1. Policy case study contributions

	General description	Authors
Data61 (Australia)	Presents the objectives, activities and mode of operation of CSIRO's Data61, the largest digital R&D centre in Australia.	Cheryl George, Adrian Turner, Peter Leihn, Kate Powl, Sandy Plunkett and Data61 team
Plattform Industrie 4.0 (Austria)	Analyses the role of Plattform Industrie 4.0 in connecting key players in business, researchers, society and politics to shape the process of digital transformation so that it benefits all players.	Rafael Boog Jasmina Schnobrich Roland Sommer Paul Trompisch
Digital Extension Centre (Chile)	Explores an initiative aimed to encourage adoption of digital technologies by SMEs in the agro-industry sector in the Maule region of Chile.	Maria José Bravo
SME 4.0 Competence Centres (Germany)	Analyses how the network of SME 4.0 Competence Centres in Germany is helping SMEs become aware of, test and adopt new digital solutions for their businesses.	Kerstin Röhling Wolfgang Crasemann
Research-Create-Innovate programme (Greece)	Explores a policy initiative aimed at promoting research in digital-related technologies that are of relevance to key economic areas in Greece.	Vasileios Gongolidis
Industry Platform 4 FVG (Italy)	Presents a public-private partnership platform created to foster digital transformation of industrial companies and the growth of ICT companies within the country's Friuli-Venezia Giulia region.	Stefano Salvador
Smart Industry Fieldlabs (Netherlands)	Explores how 10 specific Smart Industry FieldLabs support and accelerate the development, testing and implementation of smart industry solutions.	Claire Stolwijk Matthijs Punter
Digital Catapult Centre (United Kingdom)	Explores the role of Digital Catapult Centre in connecting businesses with the research and academic communities, and in helping them commercialise innovations.	Brian MacAulay and Digital Catapult team

Table RG2. Sectoral case study contributions

	General description	Authors
Digital start-ups and clusters (Austria)	Provides insights into new business models in different sectors, and explores the effect of digital transformation on innovation ecosystems. Based on an online survey, it explores how young digital companies can collaborate with mature cluster companies in various industry sectors.	Karina Wagner Gerlinde Pöchlacher-Tröschner
Digital agriculture (Italy)	Presents an overview of the main digital technologies implemented in the agriculture sector, the opportunities they offer, and adoption trends across actors. The AgriDigit project aims to expand knowledge in the field of smart agriculture to promote its implementation.	Marcello Donatelli Michele Pisante
Digitalisation of the automotive supply chain	Explores the digital transformation of the automotive industry supply chain, based on interviews conducted with industry experts in China and Germany. It provides insights into digital technology adoption across different supply chain actors, new collaboration trends, and the main challenges digital innovation faces in the sector.	Johannes Kern Pascal Wolff

Four workshops were organised in connection with the project, in order to gather experts from industry, academia and government to discuss digital transformation and its impacts on innovation. Brochures summarising the valuable input from the workshop discussions have been prepared and are available at the websites of each of the events:

- *How to leverage the digital transformation's potential for innovation and research?* (Paris, 20 June 2018), www.innovationpolicyplatform.org/digitalinnovation
- *Digital health innovations* (The Hague and Eindhoven, 11-13 April 2018), www.innovationpolicyplatform.org/digitalhealth
- *The impacts of digital transformation on innovation across sectors* (London, 21-22 September 2017), www.innovationpolicyplatform.org/londonworkshop2017
- *Innovation and the digital economy: What role for innovation policies?* (Paris, 14 June 2017), www.innovationpolicyplatform.org/digitalworkshop2017

This project was conducted jointly with the OECD TIP project on *Assessing the Impacts of the Policy Mix for Knowledge Transfer*. The project analyses the impact of public research institutions on innovation performance, and explores the policy instruments implemented across countries to support science-industry knowledge exchange.

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- Planes-Satorra, S. and C. Paunov (2019), “The digital innovation policy landscape in 2019” (working title), *OECD Science, Technology and Industry Policy Papers*, OECD Publishing, Paris.

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This project also benefited from the organisation of four workshops that gathered experts from industry, academia and government to discuss digital transformation and its impacts on innovation. The OECD team would like to thank all the speakers and participants in those workshops. The workshop of September 2017 held in London was jointly organised with Innovate UK and Digital Catapult. The workshop held in April 2018 held in The Hague and Eindhoven was organised jointly with the Dutch Ministry of Economic Affairs and Climate Policy. The OECD team would like to thank the teams involved in the organisation of those events, and particularly to David Legg (Innovate UK), Brian MacAulay (Digital Catapult) and Sander Kes (Dutch Ministry of Economic Affairs and Climate Policy).

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Acronyms and abbreviations

AI	Artificial intelligence
APIs	Application programming interfaces
AMNPO	Advanced Manufacturing National Program Office, United States
AVL LIST	Anstalt für Verbrennungskraftmaschinen List (List Institute for Combustion Engines), Austria
BEPS	Base erosion and profit shifting
BMWF	Bundesministerium für Bildung, Wissenschaft und Forschung (Federal Ministry of Education, Science and Research), Austria
BMDW	Bundesministerium für Digitalisierung und Wirtschaftsstandort (Federal Ministry for Digital and Economic Affairs), Austria
BMVIT	Bundesministerium für Verkehr, Innovation und Technologie (Ministry for Transport, Innovation and Technology), Austria
CAR	Center for Automotive Research
COMET	Competence Centre for Excellent Technologies, Austria
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
CSTP	Committee for Scientific and Technology Policy, OECD
DARPA	Defense Advanced Research Projects Agency, United States
DCCAE	Department of Communications, Climate Action and Environment, Ireland
DIIS	Department of Industry, Innovation and Science, Australia
DLTs	Distributed ledger technologies
EMA	Energy Market Authority, Singapore
ERP	Enterprise Resource Planning
FCA	Financial Conduct Authority, United Kingdom
FCT	Fundação para a Ciência e a Tecnologia (Foundation for Science and Technology), Portugal
GIS	Geographic information system
GmbH	Gesellschaft mit beschränkter Haftung (company with limited liability), Germany
GPTs	General purpose technologies
GSRT	General Secretariat for Research and Technology, Greece
HPC	High Performance Computing
HPCI	High Performance Computing Infrastructure (Japan)

HTSM	High Tech Systems & Materials, Netherlands
IEA	International Energy Agency
IFR	International Federation of Robotics
iOS	iPhone Operating System (Apple)
IOS	Internet operating system
IoT	Internet of things
INCoDe.2030	National Initiative on Digital Competences 2030 (Portugal)
IP	Intellectual property
ITF	International Transport Forum, OECD
ITIF	Information Technology & Innovation Foundation
KMU	Kleine und Mittelstandsunternehmen (Small and medium-sized businesses), German
LNI4.0	Labs Network Industrie 4.0
MIA-RTDI	Managing and Implementation Authority for Research, Technological Development and Innovation, Greece
MIT	Massachusetts Institute of Technology
MVP	Minimum viable products
NESTA	National Endowment for Science, Technology and the Arts (United Kingdom)
NHS	National Health Service, United Kingdom
OAA	Open Automotive Alliance
OEMs	Original equipment manufacturers
Ofgem	Office of Gas & Electricity Markets, United Kingdom
PSC	Public Sector Consultants
RVO	Rijksdienst voor Ondernemend Nederland (Netherlands Enterprise Agency)
SDL	Smart device link
STI	Science, technology and innovation
SWOT	Strengths, weaknesses, opportunities and threats
TIP	Innovation and Technology Policy, OECD
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organisation for Applied Scientific Research), Netherlands
TU	Technische Universität (University of Technology), German
VC	Venture capital
VDA	Verband der Automobilindustrie (Association of the Automotive Industry), Germany

Executive summary

To an ever-increasing extent, innovation is digital. Most innovations today are new products, processes or business models at least partly enabled by digital technologies or embodied in data and software. Innovation processes themselves are changing in an era of digital transformation, with the use of AI-based analytics that allow for large-scale experiments in research and new virtual simulation and prototyping techniques for developing new products.

This report describes how the digital transformation is changing innovation processes and outcomes, highlighting general trends across the economy and factors behind sector-specific dynamics. In view of such changes, the report evaluates how policy support to innovation should adapt and in what directions. It also explores novel innovation policy approaches implemented by countries to promote digital technology adoption and collaborative innovation.

Digital transformation affects innovation in all sectors, but in different ways

The digital transformation changes innovation because of the significant reduction in the cost of producing and disseminating knowledge and information – innovation’s key ingredient – that can be digitalised. Smart and connected products are very different from the tangible products that typified the previous industrial era.

Four pervasive trends characterise innovation in the digital age. First, data are becoming a key input for innovation. Second, innovation activities increasingly focus on the development of services enabled by digital technologies. Third, innovation cycles are accelerating, with virtual simulation, 3D printing and other digital technologies providing opportunities for more experimentation and versioning. Fourth, innovation is becoming more collaborative, given the growing complexity of and interdisciplinary needs for digital innovation.

Impacts of the digital transformation differ significantly, however – both among and within sectors – in three main respects. First, the scope of opportunities for innovation in products, processes and business models that digital technologies offer differ among sectors. Second, sectors need different types of data for innovation, and so the challenges faced for their exploitation differ. Third, the conditions for digital technology adoption and diffusion also vary, for instance due to differences in capabilities to take up those technologies and the level of maturity of sector-specific digital technology applications.

Key recommendations

Changes in the characteristics of innovation in the digital age require that governments change existing innovation policy instruments and mixes to respond to emerging challenges. Four new challenges for policy making that need to be addressed as a priority include the following:

1. *Develop policies addressing data access.* This now has to be a major priority in all countries. These policies are critical, as data have become a core input to innovation and data access directly affects a wide range of policy domains, such as innovation support policies, public research policies and competition policy. There is no

simple approach to data access policies, as opportunities and challenges differ across data types. A general principle is that data access policies should ensure the broadest possible access to data and knowledge so as to favour competition and innovation, while respecting constraints regarding data privacy, ethical considerations, economic costs and benefits, and intellectual property rights considerations. Policies should take into consideration the diversity of data types as well as the diversity of interests and objectives served by providing different forms of data access and data rights to their owners.

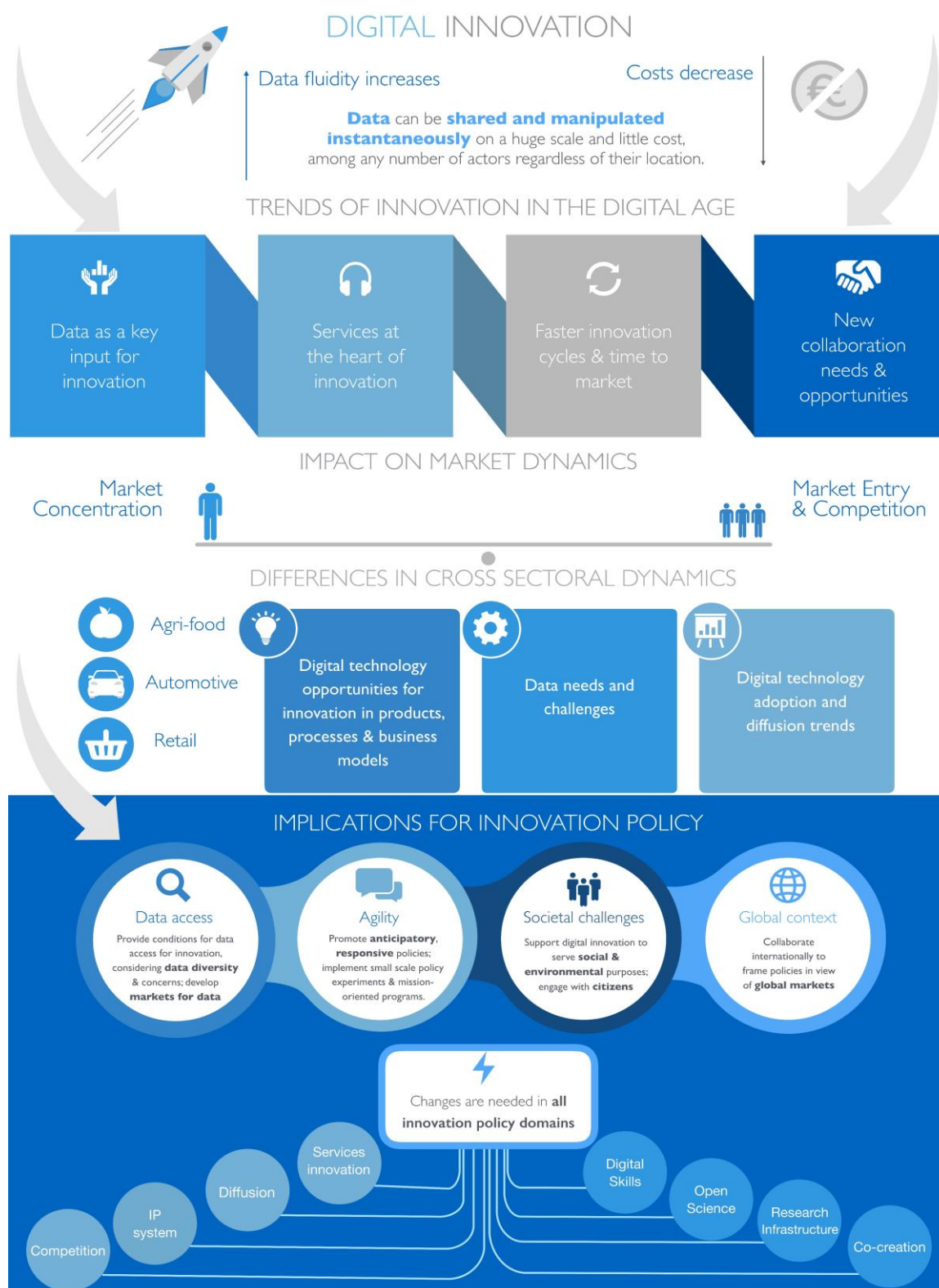
2. *Strengthen the responsiveness and agility of policies in view of rapidly changing contexts*, offering more opportunities for small-scale policy experimentation to be scaled up or abandoned depending on assessed impacts. The use of digital tools to design and monitor policy targets can also spur faster and more efficient decision making. Mission-oriented programmes setting a goal but not the means to achieve it can also increase flexibility.
3. *Support technology development that responds to societal challenges and engage with citizens* to increase trust and address public concerns regarding new digital technologies, setting the necessary (anticipatory) regulations to ensure that new technologies and applications do not harm the public interest.
4. *Consider the global nature of some of the pressing challenges affecting innovation* (e.g. data access) when designing and reforming national policies; this will involve favouring cross-country co-operation and joint action.

Other innovation policy domains would also need to be revisited to better respond to new challenges:

- *Facilitate digital technology diffusion to promote inclusion in the digital age*. Demonstration facilities, test beds and regulatory sandboxes (i.e. a mechanisms to test new products or business models with reduced regulatory requirements) are innovative tools used to encourage digital technology experimentation and adoption.
- *Support service innovation to fully benefit from the potential of digital technologies*. Revise existing support initiatives that *de facto* exclude services innovation from targeted activities, and design new programmes to address emerging needs.
- *Encourage collaboration for innovation*. Strengthen the role of knowledge intermediaries in promoting interaction and collaboration among different actors. New models for collaborative innovation could be explored, such as data-sharing initiatives, crowdsourcing, and platforms for collaboration and co-creation.
- *Promote the digitalisation of public research*. Priorities include strengthening researchers' digital skills, ensuring appropriate investments in digital tools and infrastructures for research, and setting incentives for interdisciplinary research.
- *Build digital skills, including in the field of data analytics*. Innovation authorities should collaborate with education and research authorities to identify the new skills needed in this era of digital transformation.

Data access policies, policies promoting digital technology adoption and diffusion, and policies to support the development of sectoral applications of digital technologies (where market conditions inhibited the development of private sector-led solutions) all require taking a sectoral approach when designing new initiatives, since the challenges and needs faced by sectors in these areas vary significantly.

Synthesis of the report



Main findings and recommendations

Main findings

Digital transformation affects innovation in all sectors, but in different ways

Most innovations today are new products, processes or business models at least partly enabled by digital technologies or embodied in data and software. Innovation processes themselves are changing in an era of digital transformation, with the use of AI-based analytics that allow for large-scale experiments in research and new virtual simulation and prototyping techniques for developing new products.

Digital transformation is having an impact on innovation in all sectors of the economy. Four pervasive trends characterise innovation in the digital age:

- *Data are a key input for innovation* – Data are increasingly used in innovation processes, to explore new areas of product and service development; gain insights into market trends, consumer demand and the behaviour of competitors; optimise development, production and distribution processes; and tailor the offering to specific demands and rapidly adjust to changes in demand.
- *Services are a central focus of innovation* – Digital technologies offer opportunities for innovation in services. They contribute to blurring the boundaries between manufacturing and services innovation, as manufacturers increasingly develop digitally enabled services to complement their products (the “servitisation” of manufacturing).
- *Innovation cycles are accelerating* – Digital innovations (such as virtual simulation and 3D printing) introduce new and rapid innovation cycles, by accelerating the processes of product design, prototyping and testing, as well as commercialisation. New technologies also enhance experimentation and versioning, by allowing the market launch of testing (beta) versions of products that are regularly updated to incorporate consumers’ feedback.
- *Innovation is becoming more collaborative* – Firms engage with other actors in the innovation ecosystem using a variety of tools, including data sharing; business incubation; strategic partnerships with firms, universities and public research centres; venture capital investment and acquisitions; and participation in new platforms for innovation (e.g. crowdsourcing and industry platforms). In-house collaborations across teams and departments are also increasingly encouraged.

However, impacts differ across sectors due to the different opportunities digital technologies provide to product and process innovation across those sectors. For instance, while robots have been widely deployed to automate processes in the automotive industry, automation is still at early stages in sectors such as agriculture and retail. The impacts of digital transformation differ across (and within) sectors in the following ways:

- *Digital technology opportunities for innovation* – The characteristics of industry products and processes largely influence the scope of opportunities, which may include the digitalisation of final products or processes, or the creation of new digitally enabled business models. The current and future potential for innovation (and industry disruption) offered by specific areas of technology development (e.g. artificial intelligence (AI), the Internet of things (IoT), virtual reality, 3D printing) and the scope of possible applications thus vary by sector.
- *Data needs and challenges for innovation* – Sectors also differ regarding the type of data they need for innovation. Barriers to data access differ, as for instance data needed for innovation are more sensitive in some sectors (such as patient data for healthcare innovations), or less widely accessible for technical and legal reasons. Data quality and the ease of integration of multiple databases may also differ across sectors. Some sectors may also be more attractive than others to digital talent, leading to differences in the capacities to exploit data.
- *Digital technology adoption and diffusion* – A range of factors drive differences in digital technology adoption rates across sectors, including capabilities to take up those technologies, pressures from market disruptors, and the level of maturity of sector-specific digital technology. The pace of digital technology diffusion is also influenced by the average firm size, the conditions for access to relevant infrastructure and the complexity of supply chains.

Digital innovation is changing market structures and dynamics

Digital technologies change how knowledge – the key ingredient for innovation – is produced and disseminated. Digital technologies have drastically lowered the costs of searching, sharing and analysing data. The “fluidity” of data (the fact that it is reusable, reproducible and scalable at no cost) means that once available, digitised knowledge (i.e. knowledge that is put in the form of digital data) can be shared instantaneously among any number of actors, no matter the geographic distance or other barriers.

Platforms play a central role in this context. Platforms – Internet-based structures that organise interaction among various sorts of actors – facilitate access to knowledge (patents or publication databases) and research infrastructures and the data they generate (e.g. high performance computer centres, R&D facilities), and allow for producers and consumers to meet more easily (including for niche products). They also have an efficiency-enhancing effect, in that they create standards that facilitate innovation and allow for network effects and data aggregation.

The fluidity of data and the emergence of digital platforms have two opposing impacts on market dynamics:

- *Market entry and competition* – As data are fluid and potentially available to all at a low marginal cost, the costs of market entry and expansion for new firms are lower. Digital platforms can also facilitate entrepreneurship, by lowering set-up costs for newcomers regardless of their location. Digitalisation can thus create a more level playing field for all in terms of access to inputs (if no other barriers are in place), creating a sort of equality of opportunities.
- *Market concentration* – The increasingly intangible composition of products makes it easier to expand production to the entire market at little or no marginal cost (“scale without mass”), and thus allows successful players to grow very quickly. Platforms generate important efficiency gains from combining large

amounts of data and providing a combination of services, which may give a nearly monopolistic advantage to dominant platforms (“winner take all” dynamics). The scarcity of skills required to exploit data efficiently can also contribute to concentration of talent (and thus innovation) in a few innovation hotspots.

Countries are adopting innovative policy approaches for the digital age

Digitalisation features prominently in national science, technology and innovation (STI) policy agendas, as part of main STI strategies or as dedicated national digital strategies, Industry 4.0 strategies or artificial intelligence (AI) strategies. Governments are also experimenting with novel innovation policy approaches and instruments to facilitate successful digital transformation that is inclusive. Among a diversity of policy goals are promoting digital technology adoption and diffusion across the economy, and rendering collaborative innovation more effective.

Experimental policy approaches to promote digital technology diffusion include the creation of test beds and regulatory sandboxes to facilitate testing of new digital technology applications. Innovative initiatives are also implemented to facilitate innovators’ access to state-of-the-art facilities and expertise (e.g. in the field of AI, supercomputing), and in so doing enhance early adoption of advanced digital technologies. Traditional instruments to encourage technology adoption by SMEs – such as awareness-raising campaigns, innovation vouchers, technical assistance and training – are being revisited to respond to new challenges of the digital age, and these endeavours themselves often involve use of digital tools.

New policy approaches to nurture collaborative innovation include the use of crowdsourcing and research challenges open to anyone willing to engage in finding solutions (e.g. InnoCentive), as well as the creation of living labs, to find innovative solutions to pressing challenges and encourage co-creation among various actors. Intermediary organisations, such as Catapult Centres in the United Kingdom, have become central players in innovation ecosystems, and provide services such as matching firms needing technology solutions with potential suppliers. New research and innovation centres, often public-private partnerships, have also been created to provide spaces for multi-disciplinary teams of public researchers and businesses to work together to address specific technology challenges. These often stand out for their innovative organisational structures. Examples include Data61 in Australia and Smart Industry Fieldlabs in the Netherlands. Traditional instruments such as cluster policies, the creation of networks and provision of financial support continue to be implemented but are used in new ways.

Policy recommendations

The new innovation landscape calls for changes to the targets, mechanisms and instruments of innovation policies, and to the policy mix for innovation. Four areas of priority action are critical for addressing the pressing challenges of the digital age, and constitute novel policy areas or policy approaches in most countries. In fact all innovation policy domains would need to be revisited to better respond to new challenges – for example, in the areas of technology diffusion, collaborative innovation, and public research.

Priority areas of policy action

- *Develop data access policies to promote digital innovation.* It is important to ensure the broadest possible access to data and knowledge (incentivising sharing and

reuse) to favour competition and innovation, while respecting constraints regarding data privacy, ethical considerations, economic costs and benefits (i.e. incentives to produce the data, competition) and intellectual property rights considerations. Policies should take into consideration the diversity of data types, as they significantly differ in terms of the challenges associated with their generation, access and exploitation. Appropriate conditions should also be set to allow for the emergence of markets for data.

- *Experiment with more anticipatory, responsive and agile policies.* The deployment and close monitoring of policy experiments small in scale can help assess their relevance and efficiency in a context of high uncertainty, based on which they could be easily scaled up or down or be abandoned. In a context of rapid change, it is also crucially important to streamline application procedures for innovation support instruments. Using digital tools to design innovation policy and monitor policy targets is another option to spur faster and more effective decision making. Similarly, emphasis on instruments that do not target a specific technology can increase flexibility. Mission-oriented programmes that set a goal but do not impose the means to reach it can help. Such programmes would provide the necessary autonomy and agility to choose the proper technological paths to achieve a stated policy objective.
- *Support multi-purpose digital technology development to respond to societal challenges and engage with citizens.* Policies need to ensure that multi-purpose digital technologies are developed to serve not only commercial purposes, but also social and environment purposes. Public research could support building more applications and help adoption across the economy where private business does not have the incentives to produce them. Those investments benefit from co-creation (i.e. collaboration in technology development), and from developing a shared vision around the economic, ethical, policy and legal implications of such technologies. More engagement and debate among institutions, the scientific community and the public is also needed, in order to ensure that the public is well informed about the opportunities (and risks) of new technologies and to appropriately address public concerns (e.g. strengthening privacy protection). A lack of engagement with society creates the risk of a significant future backlash, with negative impacts on the development and deployment of these technologies.
- *Set national policies in a context of global markets.* Digitalisation facilitates the circulation of knowledge, including across national borders; this reduces governments' ability to restrict the benefits of policies to their own countries. That raises a challenge for national policy makers: how can they ensure that their own citizens (and taxpayers) benefit from national policies, and that most of the benefits (e.g. income generated, productivity gains, job creations) do not leak abroad? At the same time, there are many benefits from global integration that need to be preserved. Along the same lines, there are questions about the sharing of benefits generated by exploitation of national data (e.g. from the public health system) with foreign multinationals. Co-operative solutions will be needed that allow a sharing among countries of the benefits arising from international flows of data and knowledge linked to national policies. The OECD activity on base erosion and profit shifting (BEPS) is a step in this direction (www.oecd.org/tax/beps/).

Principles for innovation policy areas that need adjustment in the digital age

- *Facilitate digital technology diffusion to support inclusion in the digital age.* Demonstration facilities, test beds and regulatory sandboxes are innovative tools used to encourage digital technology experimentation and adoption. Traditional instruments to increase technology adoption, particularly among SMEs – such as awareness-raising campaigns, innovation vouchers, technical assistance and training – remain important and could exploit the opportunities offered by digital technologies themselves (e.g. the provision of remote technical assistance). Facilitating access to state-of-the-art facilities and expertise (e.g. in the field of AI) is important for early adoption of more advanced technologies by a wider range of firms.
- *Support service innovation to fully benefit from the potential of digital technologies.* This requires revising existing support initiatives that *de facto* exclude services innovation from targeted activities, and design new programmes to address emerging needs. Initiatives may include supporting innovative projects aimed at developing new services using new digital technologies (e.g. the Smart and Digital Services initiative in Austria), or at helping manufacturing SMEs develop services related to their products (e.g. service design vouchers for manufacturing SMEs in the Netherlands).
- *Support collaboration for innovation.* Support the creation of networks or platforms to promote interactions and collaboration among different actors in innovation ecosystems (large firms, SMEs, start-ups, research institutions) (e.g. Smart Industry Fieldlabs in the Netherlands). Knowledge intermediaries, such as Fraunhofer Institutes in Germany or Catapult Centres in the United Kingdom, play a key role in transferring and adapting knowledge (e.g. advances in AI) to new applications or sectoral needs. New models for collaborative innovation, such as data-sharing initiatives, crowdsourcing and platforms for collaboration and co-creation, could also be explored.
- *Promote the digitalisation of public research.* Strengthening researchers' digital skills, for example by offering specific training and capacity-building activities for scientists, needs to become a priority to ensure that new digital tools can be integrated in research processes (e.g. machine-learning techniques). This should be accompanied by appropriate investments in digital tools and infrastructures for research (e.g. platforms for data sharing, supercomputing facilities for AI) and changes in incentives to further interdisciplinary research. Stimulating engagement in partnerships with other research institutions and with industry – and the creation of spaces for co-creation – will facilitate science-industry knowledge exchange.
- *Build digital skills, including in the field of data analytics.* Innovation authorities should collaborate with education and research authorities – to identify the new skills needed for digital transformation; to encourage university and vocational training programmes to fill critical talent shortages (e.g. data scientists), often requiring more interdisciplinary curricula; and to set up targeted training programmes for workers and awareness-raising activities for business managers (particularly in the case of SMEs) and civil servants. Specific programmes targeted at building the digital skills of disadvantaged groups would facilitate the participation of those groups in innovative activities and help address current inclusiveness challenges.

Policy areas requiring a sectoral approach

Three policy domains in particular require taking a sectoral approach when designing new initiatives, as challenges and needs faced by sectors in these areas vary significantly:

- *Data access policies* should take into consideration the diversity of data types needed for innovation in different sectors, given that access and other challenges associated with their generation, exploitation and ownership differ. For instance, precision agriculture draws mainly on sensor and satellite data, while retail exploits consumer purchasing and social media data to personalise services. In agriculture, challenges often relate to data sharing and integration, while in retail ensuring data privacy is a rising concern.
- *Digital technology adoption and diffusion policies* – such as awareness-raising schemes, training and education, demonstration and testing of new technologies, and intermediary institutions – should be tailored to the specific needs of the sector and/or type of actor (notably SMEs). Diffusion is more challenging in some sectors than in others, depending on the characteristics of production structures, level of access to intermediary institutions and infrastructures, and availability of digital capacities.
- *Policies supporting the development of sectoral applications of digital technologies where market conditions have inhibited the development of private sector-led solutions*, to ensure that such technologies provide benefits across the economy. The gap between future digital technology opportunities – including those offered by AI - and current applications differs, challenging adoption of digital technologies by firms operating in certain sectors where applications are non-existent. Public research could support the development of more applications and help adoption across the economy. Engaging with industry stakeholders and social partners to develop a shared vision for the future in key priority sectors is a useful step. Roadmaps, sectoral plans and foresight exercises are key to strengthening policy intelligence and helping align policy and industry actions in the long term, while fostering public-private collaborations.

Major changes for innovation policies called for by digitalisation



Chapter 1. Characterising innovation in the digital age

This chapter discusses how innovation is changing in the digital age. It begins by looking at the ways in which digital technologies have lowered the cost of producing and disseminating knowledge. That dynamic has led to four key changes in innovation practices and outcomes that are explored in detail: data are becoming a key input for innovation; there is an increasing focus on services innovation enabled by digital technologies; innovation cycles are accelerating, as the possibilities for experimentation and versioning expand; and collaboration is becoming a more critical component of innovation. The chapter also discusses the effects of such changes on market dynamics and the distribution of rewards across businesses, individuals and regions.

Introduction

Most innovations today are at least partly enabled by digital technologies or embodied in data and software. Digital technologies are enabling the creation of new digital or digitally enabled products and business models (such as social media networks, online marketplaces, on-demand mobility services) as well as the enhancement of traditional ones, as exemplified by connected cars.

Digital technologies are also enabling innovation in production and distribution processes, allowing for instance to automate processes with robots, trace products along value chains, better manage stocks with the use of sensors and the Internet of Things (IoT), and predict the maintenance needs of equipment with big data analytics.

Many new opportunities are also arising for accelerating and improving R&D processes. These include the use of big data analytics and large-scale computerised experiments for research, and virtual simulation and 3D printing for developing, prototyping and testing new products.

Today, the effects of digital technologies are felt in all sectors, changing innovation practices and outcomes not only in “born digital” sectors, but also in traditional ones such as agriculture, transportation and retail – as indeed would be expected of general purpose technologies (GPTs) (see Paunov and Planes-Satorra, 2019). GPTs are defined as technologies that drive innovation across the economy and bring long-term social, economic and productivity benefits, as was the case with the steam engine, electricity, the automobile, the computer and the Internet in the past (David, 1990; Bresnahan and Trajtenberg, 1995). What are the characteristics of innovation in the digital age?

This chapter explores how the digital transformation is changing innovation processes and outcomes across all sectors of the economy, and the effect of such changes on market dynamics.

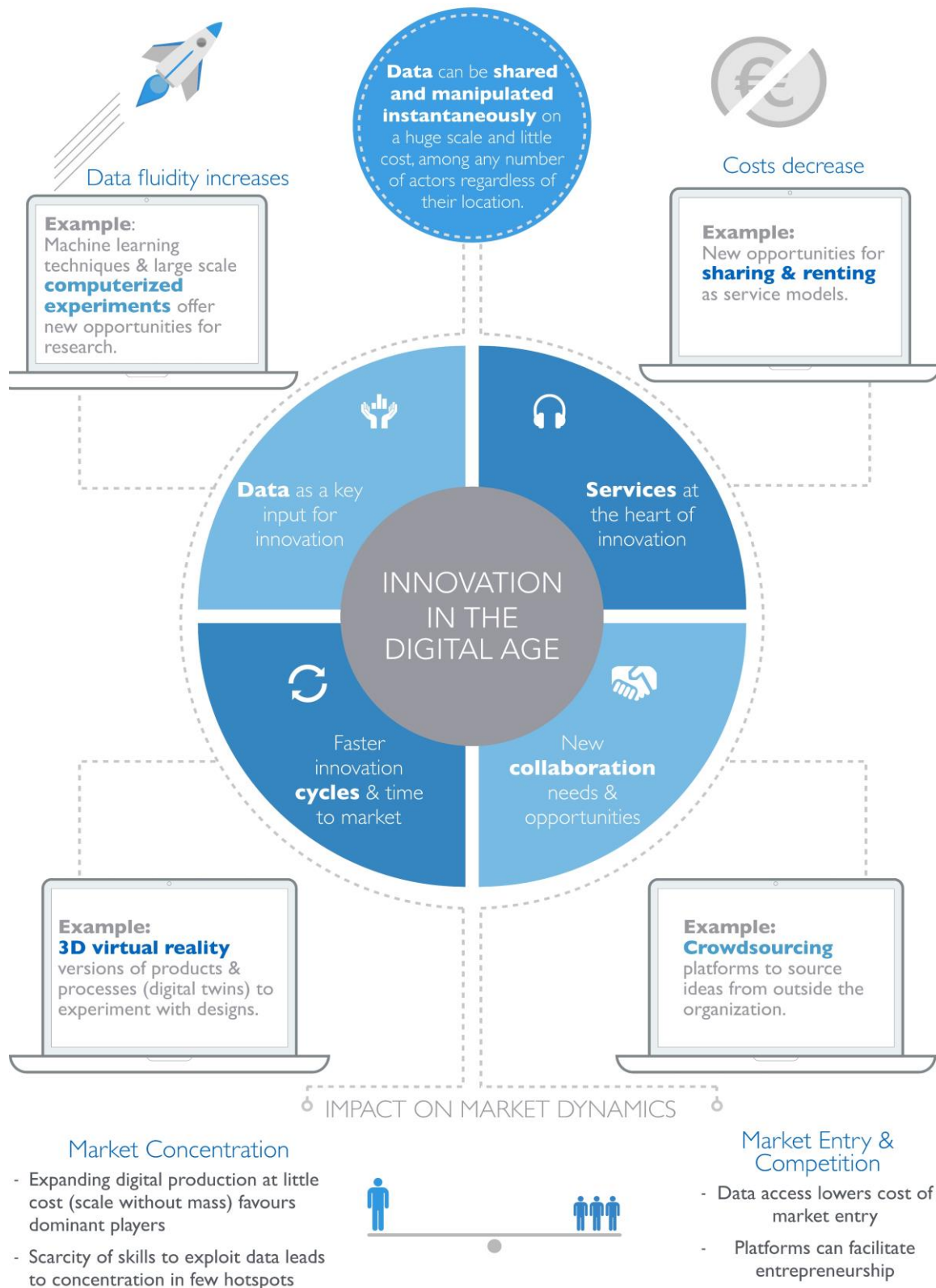
The chapter finds that digital transformation changes innovation because digitalisation significantly reduces the cost of producing and disseminating the sort of knowledge and information – innovation’s key ingredients – that can be digitalised. Smart and connected products are very different from the tangible products that characterised the previous industrial era.

Four changes in innovation dynamics witnessed across all sectors are identified here. First, data are becoming a key input for innovation. Second, innovation activities increasingly focus on the development of services enabled by digital technologies. Third, innovation cycles are accelerating, with virtual simulation, 3D printing and other digital technologies providing opportunities for more experimentation and versioning in innovation. Fourth, innovation is becoming more collaborative, given the growing complexity and interdisciplinary needs of digital innovation.

These transformations in innovation processes and their outcomes in turn affect business dynamics and market structure, and consequently have implications for the distribution of performance and rewards among businesses, individuals and regions.

This chapter is structured as follows. Section 1.1 discusses the main ways in which innovation is changing in the digital age, while Section 1.2 discusses the effects on market dynamics and consequent implications for innovation. Section 1.3 concludes.

Figure 1.1. Synthesis of chapter 1



1.1. How is the digital transformation changing innovation?

Lower production costs and fluidity

Digital technologies change the very way knowledge and information are produced and disseminated. The processes and products embodying or implementing digital technologies are characterised by their “fluidity”. Fluidity means that data can circulate and be reproduced, shared or manipulated instantaneously, on a huge scale and at little cost. Once available, digitised knowledge (i.e. knowledge that takes the form of data) or information can be shared instantaneously among any number of actors, regardless of their location (OECD, forthcoming).

Increasingly, this fluidity is transmitted throughout the entire economy, as even tangible products increasingly embed digital components, transforming them into smart, connected products (e.g. connected cars and agricultural machinery equipped with sensors). Such products are able to produce and exchange data concerning their own status and performance, or the environmental conditions around them (the Internet of things, IoT).

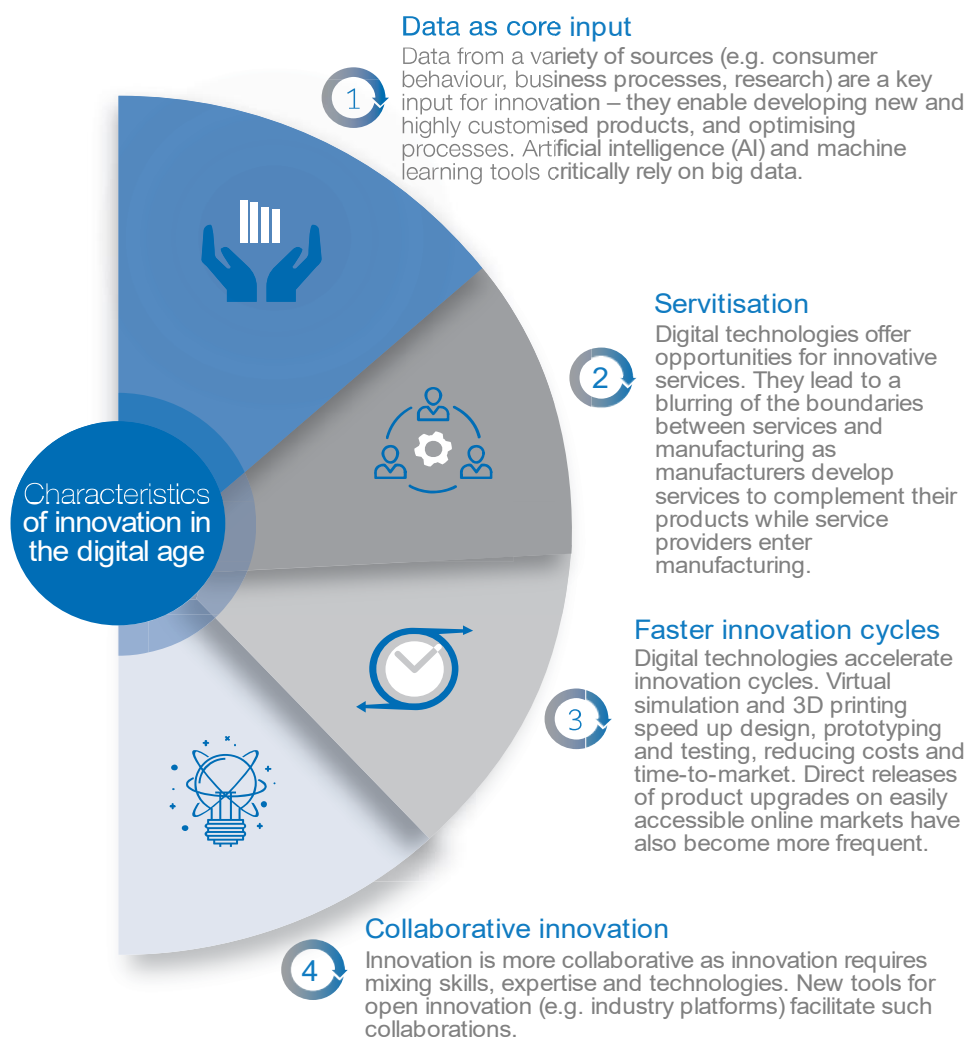
Smart and connected products are found throughout all industries. In agriculture, machinery is now equipped with a large number of sensors that capture information about the conditions of the crop, allowing for the development of smart farming services. In the automotive sector, connected cars generate data from the physical world, receive and process data, and connect to other cars and devices. Connected cars allow for enhanced driver safety and convenience, with services such as automatic emergency calls after an accident, real-time road hazard warnings to drivers, systems of networked parking that reduce time for parking, and navigation systems that optimise route planning and report real-time traffic conditions to the driver. Self-driving cars, currently tested in pilot projects, will be able to drive autonomously and react to their environment without the intervention of the driver.

Knowledge “fluidity” reduces several costs linked to its production and dissemination, as well as the costs of development, production and commercialisation of new products. In particular, it reduces: i) the costs of searching, verifying, manipulating and communicating information and knowledge; ii) the marginal costs of producing goods and services that are mainly or completely intangible, and iii) the costs of launching new goods and services on the market, specifically those with high information and knowledge content. (For more details on the impacts of digital technologies on the handling of knowledge, see Guellec and Paunov, 2018 and Haskel and Westlake, 2017.)

New characteristics of innovation

The lower cost of producing and disseminating knowledge via the digital transformation is changing innovation throughout sectors in four ways: 1) data are becoming a key input for innovation; 2) innovation efforts increasingly focus on services innovation enabled by digital technologies; 3) innovation cycles are accelerating, with more possibilities for experimentation and versioning; and 4) innovation processes are becoming more collaborative (Figure 1.2).

Figure 1.2. Characteristics of innovation in the digital age



(1) Data as a core input for innovation

Data are a key driver of innovation. Exponential growth in the generation of data of various types (e.g. personal, business, research), and new possibilities for gathering and exploiting such data, have made them core inputs of innovation in all sectors of the economy (OECD, 2015a). The development of IoT contributes to steady increases in data generation, as more devices and activities are connected. The deployment of AI and machine learning further increases the expected value of data.

Data and data analytics offer opportunities for research (e.g. use of machine learning and large-scale computerised experiments) and stimulate innovation, among others in the following ways (Figure 1.3) (OECD, 2015a; OECD, 2018).

Figure 1.3. **Data and data analytics: Opportunities for research and innovation**

Changing research processes

The way research is conducted is also changing in many scientific disciplines. The large amounts of data available today and the improved conditions for exploiting them, including with machine learning techniques, allow for conducting large-scale computerised experiments and exploiting information repeatedly, and on a scale that is unprecedented.

Enabling new services and business models

Data have allowed the development of completely new services and business models. Smart farming services, peer-to-peer accommodation services (e.g. Airbnb), on-demand mobility services (e.g. Uber), peer-to-peer ride sharing (e.g. BlaBlaCar) and platforms to search, compare and book accommodation and transportation options (e.g. Booking) are examples enabled by the availability, and capacity to exploit, large amounts of real-time data.

Enhancing customisation

Customer data provide important information regarding consumer preferences and needs, which firms increasingly exploit to customise their products. Retailers are increasingly personalising discounts and advertisements using customer purchasing and browsing data. For instance, Sephora uses data from customers' online shopping histories, by employing

beacons in their stores which send smart-phone notifications when customers are near an item they had previously added in a digital shopping cart (Pandolph, 2017).

In the health sector, precision medicine is an emerging approach that aims to tailor treatments to individual patients, taking into account their genomic and other biological characteristics, as well as health status, previously prescribed medications and environmental and lifestyle factors. Such advances are enabled by the exploitation of large amounts of patient data and the use of AI and machine learning tools.

Optimising processes

Business data are increasingly used to optimise processes within firms but also within supply chains. Manufacturing sectors exploit abundant real-time shop floor data to identify patterns and relationships among discrete processes in order to optimise them – e.g. in terms of waste reduction, energy savings, increased flexibility, and better asset utilisation (OECD, 2017). For example UPS, a multinational logistics company, uses a fleet management system enhanced by data analytics that allows for route optimisation, increasing the efficiency and flexibility of delivery processes and reducing fuel consumption. Data are also used to predict the maintenance needs of production systems, significantly lowering maintenance costs compared with regular maintenance and repair activities. In agriculture, data from a multiplicity of sensors can be used to help farmers optimise the use of water and other inputs to boost yields.

Advanced Enterprise Resource Planning (ERP) systems that apply data analytics to optimise end-to-end supply chain planning – increasing its flexibility and capacity to respond to shifts in demand – are also used to a greater extent by firms (Geissbauer et al., 2017). For instance, Amazon has created algorithms to automatically respond to changes in demands: when the popularity of a product increases, the system automatically feeds information into the supply chain system to optimise the inventory, and introduces changes in pricing to maximise benefits (Reeves and Whitaker, 2018).

Blockchain and other distributed ledger technologies (DLTs) – immutable, encrypted and time-stamped databases in which data are recorded, validated and replicated across a decentralised network of nodes – are expected to offer a range of new opportunities for process innovation in the near future. These databases enable parties that are geographically distant to record, verify and share digital or digitised assets on a peer-to-peer basis with fewer or no intermediaries (Nascimento, Polvora and Sousa Lourenço, 2018). For instance, the start-up Provenance uses blockchain along with mobile and smart tags to track physical products and verify their claims (e.g. proof of fair payment, social and environmental sustainability of activities) from the origin to the point of sale (Provenance, 2018).

(2) Services innovation enabled by digital technologies

The digital transformation offers opportunities especially for innovation in services, as data and software are replacing many physical components and products. Opportunities arise in particular for the creation of entirely new digitally enabled services, such as predictive maintenance services using the IoT, on-demand transportation services (e.g. Uber), and web-based business services. New digital technologies have also propelled the expansion of sharing or renting as service models that replace selling (e.g. of equipment), and the customisation of products as a service (i.e. adapting products to customers' specific needs, allowed by software and data).

These opportunities, coupled with rising competitive pressures linked to the entry of digital players in traditional sectors and changing consumer demands, are pushing incumbent manufacturing firms to offer new digitally enabled services, while service providers increasingly build on digital technologies to improve their offering. Such trends contribute to blurring the frontier between manufacturing and services.

Manufacturing firms expand into digitally enabled services

Manufacturing firms are increasingly offering services as a complement to the goods they produce – a process known as “servitisation” of manufacturing. Servitisation is largely enabled by the proliferation of smart and connected features of products, which allow for real-time monitoring of products’ status, performance and usage, and by growing data analytics capabilities. By offering new services, manufacturers aim at strengthening their competitive advantage and creating new revenue streams.

Servitisation is unlocking opportunities in practically all manufacturing sectors. John Deere, an agricultural machinery producer, has developed a software platform that provides farm management support services based on data collected from a wide range of sensors installed in its equipment, combined with historical data on weather and soil conditions and crop features, among others. In the automotive industry, carmakers are increasingly providing after-sales services, such as predictive maintenance services. Many have also created their own car-sharing schemes (to provide on-demand mobility services) and experiment with alternatives to car ownership (e.g. vehicle subscription services and autonomous cars).

Services innovations build on digital technologies

Service providers are significantly investing in digital technology development to improve their activities. Big retailers are for instance investing intensively in data collection and data analytics capabilities (e.g. to personalise promotions and predict consumer trends), augmented and virtual reality (e.g. to develop digital mirrors that enable customers to easily try clothes on virtually in the physical store) and IoT (e.g. to improve inventory management). These investments aim at enhancing the consumer experience and optimising retailers’ activities. Farm insurance services are also investing in advanced data-collection technologies (e.g. drones, sensors) to assess damages suffered after severe weather events, fire, etc.; these technologies significantly reduce costs linked to field inspections and accelerate insurance claim processes by farmers. The tourism and cultural sectors are also benefiting from the possibilities offered by digital technology innovations. Augmented reality applications are, for instance, used to enhance the visitor experience in historical sites and museums.

(3) Faster innovation cycles

Digital technologies allow accelerating innovation cycles – reducing R&D costs and time-to-market significantly – due to the new opportunities they offer for more experimentation and versioning.

Designing, prototyping and testing new products and services

New digitally enabled technologies, such as virtual simulation (made possible by visualisation technologies such as augmented reality) and 3D printing, significantly reduce the cost and time devoted to designing, prototyping and testing processes. They allow testing ideas earlier in development and facilitate multiple iterations and adjustments.

Engineers and designers across manufacturing industries increasingly use “digital twins” (i.e. a 3D virtual reality version of a production process or a product) to experiment with designs. In the automotive sector, engineers use design simulation tools to optimise the shape and material properties of parts; they can thereby judge their interactions with other parts, the ease of manufacturing and assembly, and their response to crush-test conditions (Schoenberger, 2014). In the construction sector, specialised software allows design components to fulfil specific functions optimising material (Lehne and Preston, 2018).

Experimenting with (not fully finished) products and services on the market

Digital innovations are often launched to the market even when they are not in their fully finished version (i.e. in beta versions), allowing for more experimentation and product fine-tuning based on consumers’ feedback and real-world product performance data. For instance, Tesla Motors installed a “public beta” of its AutoPilot software in more than 70 000 vehicles to test its robustness in different traffic scenarios (Lambert, 2016).

Many firms are also adopting a “lean start-up” method, which consists of creating minimum viable products (MVP) that can be brought to the market. Once launched, producers collect feedback from users and integrate it into their next development round. For example, GE Appliances’ FastWorks system, based on lean innovation principles, involves consumers early in the development of new products such as refrigerators (General Electric, 2017).

One factor that could, however, hold back immediate testing with customers is any impact on brand reputation that may come from launching an incremental innovation that is defective or simply judged to be of less value by customers.

Regular upgrading and versioning

Many products with digital components allow for regular upgrades, so innovation often does not require releasing an entirely new product but simply consists of an “add on” to products already in the market. Tesla Motors’ cars for example can receive software updates “over the air”, similarly to iOS updates in iPhones. This cumulative nature of upgrades reduces the “cannibalisation” of products (i.e. the creative destruction of its own product by a company): new digital products will not replace existing products of firms, but instead reinforce them.

Such upgrades are however only applicable to the digital components of products. Sectors such as automotive manufacturing, where an important part of innovation is still connected to physical components, have the challenge of devising innovation strategies that consider the co-existence of parallel innovation cycles that run at different speeds. Furthermore, acceleration in versioning and innovation is not synonymous with more rapid technological progress or productivity; many of these frequent improvements are small.

Personalisation

Digital technologies also increase the flexibility of manufacturing, enabling small series production at low cost (similar to the cost of mass production) and thus higher personalisation of products to respond to customers’ specific requirements and niche markets. Production responds to orders, which automatically pass through the production planning process to the machine control; the machine then reconfigures itself to process the individual orders. 3D printing can represent a significant enabler technology within this context. Smart products can also be personalised through software rather than hardware. e.g. pay-per-function (Wagner and Pöchhacker, 2019; Stolwijk and Punter, 2019).

(4) Collaborative innovation

Innovation ecosystems are becoming more and more open and diverse. Firms increasingly interact with research institutions and firms, for three reasons. First, this allows them to gain access and exposure to a richer pool of expertise and skills that are complementary to their own competencies (e.g. data analytics). Access to talent is expected to spur creativity and enable innovation in new areas (e.g. integration of data in innovation activities and the servitisation of manufacturing described above). Second, such collaborations allow sharing the costs and risks of uncertain investments in digital innovation. Firms often face several potential research and technology development paths, the mastery of any of which requires large-scale investments with uncertain outcomes. Engaging with others is a way to expand into different areas while collectively sharing costs. Third, reduced costs of communication allow greater interaction among actors engaged in innovation (e.g. firms, public research institutions), regardless of their location.

Collaborations take different forms: 1) data sharing; 2) business incubation; 3) open innovation among actors (e.g. partnerships between firms and digital start-ups, universities); 4) platforms and other innovation ecosystems; and 5) corporate venture capital investments and acquisitions. In this context, new schemes are also set to encourage in-house collaborations.

Data sharing

The non-rivalrous nature of data allows the same database to be used simultaneously by various actors from different organisations, even if they are located in different places around the world. This has stimulated firms to share their data for research and innovation purposes, often with universities and research organisations or trusted business partners. An example is sharing data with supply chain partners to optimise processes. In the field of retail, for instance, the Kellogg Company analysed point-of-sale (POS) data from Tesco Supermarkets to identify purchasing patterns and adjust its shipping schedules; it can thereby recover the cost of lost sales and increase consumers' satisfaction (Harper et al., 2009).

Firms are also increasingly making data they are not currently exploiting available to the wider public – for example, with application programming interfaces (APIs), streams of data are made available for developers to create new business opportunities and applications, or to improve existing products. Challenges and hackathons are other popular tools for sourcing external ideas to foster data-driven innovation. Hackathon competitions are 24-to 48-hour events in which participants are provided with data with which they have to create an innovative product, often an app. Winners are typically compensated with incubating opportunities (Grijpink, Lau and Vara, 2015).

Business incubation

Firms establish incubator and accelerator programmes to engage with innovative start-ups at their early stages of development, by providing them with support for a certain period. Although not new, incubation use has significantly increased with digital transformation. The start-ups targeted are often digital companies functioning in domains adjacent to the firm's core area of business. For instance, Walmart has created Store No. 8, a technology start-up incubator. Located in Silicon Valley, Store No. 8 aims at identifying new technology developments that will reshape the retail industry, such as in the area of autonomous vehicles, virtual and augmented reality, and drone delivery. The incubator is also seen as a tool to attract new digital talent.

Open innovation among actors

Open innovation refers to innovation beyond the boundaries of the firm. It involves collaborations with other business, public research and university partners. This co-operation can be about collaborating in research, dividing research work between partners, pooling results, etc. Open innovation existed before digitalisation, but has progressed with it because of cost reductions as well as other push factors, such as the advantages from interdisciplinary work. The goal of such partnerships is to join efforts to produce joint value, expand market potential, and combine strengths in a way that allows closing skills or competence gaps. This often involves the creation of a new legal entity, or sharing a range of infrastructures, investments or assets. Data sharing is at the core of many of those strategic partnerships; it is in firms' interest, however, to limit access to data that constitute strategic advantages.

Partnerships with large technology firms such as Google – and other firms with deep expertise in specific areas of technology development or business model innovation – are expanding across sectors. Some examples include John Deere's partnership with Sentra, a global provider of precision agriculture software and drones (Sentra, 2017); Toyota's partnership with Microsoft to develop new Internet-connected vehicle services (Lienert, 2016); and the partnership between Rebecca Minkoff (a fashion retailer) and eBay to create a digitally connected store – with digital and smart fitting rooms to improve the in-store experience of customers – while collecting data about customer preferences and trends (Alvarez, 2016).

Collaborations with digital start-ups have also boomed in recent years. Firms in traditional sectors see opportunities for start-ups to function as “digital accelerators”, since they often enjoy greater flexibility in developing new disruptive technologies (Lund, Manyika and Robinson, 2016). Such engagements are also a way of externalising the risk of certain R&D activities. Digital start-ups' incentives to collaborate with large players include accessing funding, sectoral expertise or capabilities, new markets, and important assets (such as business data). For instance, in 2017 Ford announced its USD 1 billion investment in Argo AI, a technology start-up with major competencies in robotics and artificial intelligence software (Forbes, 2017). Wagner and Pöchlhammer (2019) explores the main areas of co-operation between Austrian cluster companies and start-ups (e.g. big data and smart solutions, business model innovation) and identifies challenges that were faced.

Partnerships are also often established with universities or public research centres. These are critical for accelerating the translation of research findings into marketable innovations in a context of rapid change. Examples include the digital research partnership between Origin Enterprises (an agri-services firm) and University College Dublin, an institution with strong multidisciplinary research teams, including in the fields of advanced data analytics, sensing technologies, modelling and agriculture science (Origin Enterprises, 2016); and the research alliance between Bosch (a major automotive supplier) and the University of Amsterdam (the Delta Lab) that focuses on the AI field of deep learning (Bosch, 2017).

Sometimes collaborations go beyond one-to-one partnerships and involve the creation of longer-term partnerships with many actors, sometimes supported by dedicated policy initiatives. For instance, the R&D centre Virtual Vehicle in Graz (Austria) brings together more than 80 industry partners and 40 scientific institutions that collaborate in research for advanced virtualisation of vehicle development. The Competence Centre for Excellent Technologies (COMET) programme supports it with research funding (Virtual Vehicle, 2018).

Platforms and other innovation ecosystems

Innovation ecosystems are made up of groups of businesses (small and large, old and new) engaged together directly or indirectly in open innovation, plus universities, capital (notably venture capital, VC) and service providers (e.g. intellectual property [IP] management). These ecosystems constitute the locus of most innovation, and are increasingly engaged in new activities, including adoption of open standards and participation in industry platforms and crowdsourcing platforms.

Industry platforms can be defined as products, services or technologies created by one or several firms and that provide the foundation upon which different actors can innovate by developing complementary products, services or technologies using digital tools (Gawer and Cusumano, 2014). A platform can serve in this way as the (*de facto*) industry standard – making development processes more efficient and less costly, enabling rapid innovation, and accelerating time-to-market for new products. There are also different degrees of platform openness: some are restricted to certain users and others are totally open. For instance, in 2013 John Deere opened its software platform to third parties (e.g. input suppliers, agriculture retailers, software companies) for them to develop applications and software that connect through the platform. An example in the automotive sector is the SmartDeviceLink Consortium, created in 2016 by Ford and Toyota; this is an open source platform for smartphone app development for vehicles, that aims to become the industry standard for in-vehicle application connectivity (OAA, n.d.; SDL, 2018).

In the field of AI, there is an open standards approach taken by companies such as Microsoft, Facebook and Google: they open platforms where innovators can come and borrow tools and upload their creation. Hence they constitute a community of developers.

Crowdsourcing platforms are tools used by firms to source ideas from outside the organisation (either the general public or a pool of accredited experts) to solve a specific problem or challenge, or find a new product, or to design ideas. Typically, firms present their challenge on line and innovators (be they designers, scientists, start-ups or experts) can present their proposals within a given timeline. Selected solutions can then be adopted by the firm, while the innovator receives the agreed reward (e.g. a fixed monetary reward, ownership of IP rights). In many cases, such initiatives are conducted through intermediary platforms (some sector-specific), such as Innocentive, IdeaConnection, Innoget, Hypios or NineSigma. These benefit from network effects, as they are able to reach to a wider range of experts across the world (Board of Innovation, n.d.). In other cases, initiatives are established by firms themselves. For instance, in the field of food processing, General Mills has created the G-WIN platform to crowdsource innovative ideas, from packaging to new production technologies (General Mills, 2018).

Corporate venture capital investments and acquisitions

Venture capital investments on, and the acquisition of, innovative firms (particularly start-ups) by established firms is also a channel for collective innovation. Start-ups play a key role in discovering and testing new products, markets and business models; when successful, they are usually acquired by larger firms with access to capital and markets that can scale up the successful product. This has been systematised by many large companies that have set up their own venture capital fund, which allocates capital notably but not exclusively to spin-offs created by in-house engineers with breakthrough ideas. For instance, Alliance Ventures, a fund launched in 2018 by Renault, Nissan and Mitsubishi, pursues strategic investments in start-ups at all stages of maturity developing disruptive

technologies or business models in the fields of new mobility, autonomous systems, connectivity, and artificial intelligence.

New market players are also using acquisitions to expand into new activities and gain access to markets and data. An illustrative example is Amazon's acquisition of Whole Foods, giving the former access to consumer data on affluent shoppers, and so allowing it to explore grocery shopping habits and preferences (Petro, 2017). Another pertinent example is Microsoft's acquisition of LinkedIn.

In-house collaborations

Pressures to increase the rate and speed of innovation have also led many firms to create their own (digital) innovation labs, also called innovation hubs or innovation garages, where it is the job of specific teams to experiment with and test new ideas for the development of new products, services, business models or customer experiences. These labs encourage workers to think “outside the box” and adopt an entrepreneurial mentality. In order to provide a start-up-like environment, these labs are often separated from corporate offices, and sometimes located in high-tech clusters such as Silicon Valley to benefit from spillovers and trigger new collaborations. They typically have multidisciplinary teams that include data scientists and software developers, researchers and designers (Internet Retailing, 2015). Examples can be found in many different industries (e.g. Tesco Labs and Argos Digital Hub in retail, Volkswagen Automotive Innovation Lab).

Firms are also engaging in initiatives to stimulate creativity and collaboration within their organisations. For example, the Renault Creative People initiative encourages Renault's employees to propose innovative ideas. The best proposals are then prototyped in the Renault Creative Lab. Another of Renault's recent initiatives is the Cooperative Laboratory for Innovation, which stimulates collaboration among product, design and engineering departments to spur creativity (Groupe Renault, 2018).

1.2. What are the impacts of digital innovation on market dynamics?

The transformations in innovation processes and their outcomes described in Section 1.1 affect business dynamics and market structure.¹ In particular, the fluidity of data and the emergence of digital platforms have two opposing impacts on market dynamics and income distribution. On the one hand, they can foster market entry and competition; on the other, they can lead to market concentration and distributional challenges. Competition dynamics have direct impacts on innovation, as the competitive environment influences firms' incentives to innovate, and consequently the rate of innovation and innovation-driven growth (Romer, 1990; Aghion and Howitt, 1992; OECD, 2015b).

The balance between factors favouring and hampering concentration varies over time and sectors, and can be influenced by policies. Polarised market structures simultaneously characterised by both dynamics are also a possible development, with a few giants on the one hand and a long tail of smaller and fast-changing niche producers on the other. While market concentration is considered unfavourable to competition, entrepreneurial dynamics

¹ The influence of digitalisation on the developments described in Section 1.2 does not preclude the influence of other factors, such as globalisation, new financial products, framework conditions, etc. Often these factors interact with digitalisation to either reinforce or inhibit such developments.

is a strong competitive factor. The coexistence of concentration and entrepreneurship in markets thus raises new questions about competition – and therefore about innovation.

Facilitating market entry and competition

A range of factors is driving the entry and growth of new firms, and thus stimulates market competition as these firms challenge incumbents. First, as has been shown, data are fluid and potentially available to all at a low marginal cost. Depending on the type of data, different companies and individuals, regardless of their location, can exploit the same data, thus providing opportunities in markets for more participants. This contrasts with traditional markets for tangible goods, where inputs are available in limited quantities and at a significant cost. This has allowed for dynamic entrepreneurial activity. The transportation sector, for instance, has seen the emergence of platform-based car-sharing and ride-hailing applications, largely building on data; in retail there are now start-ups specialised in data analytics to optimise inventories and personalise sales. The highly successful start-ups created by students using digital technologies and data (e.g. Facebook by Mark Zuckerberg and Snapchat by Evan Spiegel) are also a good illustration of such new dynamics of the intangible economy.

Second, digital platforms facilitate entrepreneurship by lowering set-up costs for newcomers, as for example in the case of e-commerce platforms (e.g. Alibaba, Amazon and eBay) on which new ventures can offer products to the global market without having to deal with additional marketing expenditures (Brynjolfsson, Hui and Liu, 2018). Firms can also create their own online store, building on the tools and advice offered by e-commerce software providers such as Magento and Shopify.

The cloud and other off-the-shelf digital tools – including open source software, open access depositories of data, and information and knowledge available on line – also reduce costs for small firms and new entrepreneurs.

Market dynamics

Several factors may favour concentration. One is the natural advantage of platforms – Internet-based structures that organise interaction among different actors – in increasing market efficiencies. Important efficiency gains come from combining and exploiting the data platforms gather. Large aggregators of data, such as Google and Amazon, thus benefit from a natural advantage. Similarly, the provision of combined services on a single platform that brings together a larger group of users offers major consumer benefits. In other words, several small platforms that provide fewer services, have fewer users each, and build on fewer data would be much less efficient than a single, large platform. Such economies of scale are a characteristic of natural monopolies (Tirole, 2019).

The second factor arises from “scale without mass”, a consequence of the increasingly intangible attributes of products. The larger the intangible component of a product, the easier it is to expand production to the entire market at little or no cost. In the extreme, as in the case of software, the cost of producing an additional unit is close to zero since no further set-up costs are involved. The much smaller number of employees of certain digital companies compared to companies in traditional industries with similar sales levels illustrates this dynamic.

A third factor is the scarcity of certain elements required for efficient exploitation of data: skills are the most important of these. Such scarcity may favour concentration in a few firms and innovation hotspots. The concentration of highly innovative companies in

Kendall Square close to MIT in Cambridge, Massachusetts demonstrates the role of extreme proximity, notably for research activities. Skilled workers benefit from close interaction, and skilled labour is complementary to data. With a more diversified set of expertise needed for digital innovations – as exemplified by the modern car that requires optimised engineering and computing abilities – skills needed to exploit data opportunities can best be found in urban areas that pool large numbers of persons possessing different kinds of expertise. The rise of cities also reflects the complementarity of non-codified knowledge with codified digital knowledge. Gaspar and Glaeser (1998) suggest that reductions in communications costs may most benefit those who already interact a great deal, in which case falling costs would benefit cities most (strengthening concentration further).

Concentration is reinforced by the fact that markets are now globally integrated, whereas in the past national borders shielded places, people and firms from foreign competition, and so limited global concentration. Modern innovation policies are designed with additional considerations of their impact on society – and such considerations should not be overlooked by policy makers (OECD, 2015b).

1.3. Conclusion

The chapter shows that the digital transformation changes innovation because digitalisation significantly reduces the cost of producing and disseminating knowledge – innovation’s key ingredient – and makes knowledge and information fluid. Four changes in innovation dynamics across all sectors are identified. First, data is becoming a key input for innovation. Second, innovation activities increasingly focus on the development of services enabled by digital technologies. Third, innovation cycles are accelerating, with digital technologies providing opportunities for more experimentation and versioning for innovation. Fourth, innovation is becoming more collaborative, given the growing complexity and interdisciplinary needs for digital innovation. The digital transformation also affects market dynamics, affecting the rate of innovation and having distributional impacts.

This chapter is but a first step in understanding the changing characteristics of innovation in the digital age. An important priority for policy research in this field must involve gathering the evidence on firms’ use of AI, big data analytics and digital technologies for innovation, and implications on how they innovate – including notably the degree of experimentation and versioning, the extent to which they innovate services, and the level of intensity with which they collaborate with others. The evidence should also look into differences in the pace of adoption across firms, sectors, regions and countries, to better detect the specific factors spurring and restraining digital innovation. This is not an easy task, as new data are needed to make such an assessment possible.

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Chapter 2. Impacts of the digital transformation on innovation across sectors

This chapter explores how the digital transformation changes innovation, beginning with profiles of the agri-food, automotive and retail sectors. It goes on to examine differences across sectors in terms of the opportunities for innovation offered by new digital technologies, noting the data needs and challenges involved. Factors behind differences in adoption and diffusion rates are also discussed, including varying capabilities to take up new technologies and diverse competitive landscapes. The chapter concludes by pointing to important within-sector heterogeneities.

Introduction

Since industries significantly differ in their products and processes, their structures, and in how they engage in innovation, the impacts of digitalisation on their innovation are unlikely to be the same. For instance, end products in primary sectors such as food or mining remain largely unchanged, while the media, music and gaming industries have completely digitalised their offering over the past decades. Production and innovation processes have also been transformed by digital technologies, but in different ways: while robots have been widely deployed to automate processes in the automotive industry, automation is still in its early stages in sectors such as agriculture and retail. Understanding these differences matters for policy aimed at supporting innovation systems, as countries' industry composition differs markedly.

This chapter describes how the digital transformation affects three distinct sectors – agri-food, automotive and transportation, and retail – to illustrate the nature of change in the primary, manufacturing and services sectors (see full analysis in Paunov and Planes-Satorra, 2019).

The chapter finds that three main dimensions shape the differences in impacts of digitalisation on innovation across sectors: 1) the scope of opportunities for innovation that digital technologies offer; 2) the types of data needed for innovation and the challenges faced with regard to their exploitation; and 3) the conditions for digital technology adoption and diffusion. The chapter also shows evidence of important within-sector heterogeneities.

The chapter is structured as follows. Section 2.1 provides an overview of how the digital transformation is changing the agri-food, automotive and retail sectors. Section 2.2 explores sectoral differences in digital technology opportunities for innovation. Section 2.3 examines sectoral differences in data needs and challenges for innovation. Section 2.4 presents the factors behind cross-sectoral differences in digital technology adoption and diffusion rates, while Section 2.5 looks at important factors affecting differences within sectors. Section 2.6 concludes.

Figure 2.1. Synthesis of chapter 2



2.1. Current sector-specific digital technology applications

Sectoral applications of digital technologies tend to build on digital technologies in very different ways, shaping transformations across sectors differently. For example, healthcare innovations draw significantly on advances in AI and biotechnology, while consumer products and services rely more on advances in IoT (De La Tour et al., 2017). This section shows how digital technologies are currently integrating and transforming the agriculture, automotive and retail sectors aside from the common impacts digital technologies have across all sectors (as described in Chapter 1).

Agri-food sector

In agriculture, intelligent and digitally connected machinery (IoT) enables the development of “precision farming” – that is to say, systems that help farmers improve the accuracy of operations and optimise the use of inputs (e.g. water, fertilisers, pesticides) to give each plant (or animal) exactly what it needs to grow optimally. Tractors and other agricultural machinery are now equipped with a large number of sensors that capture information about crop conditions (e.g. soil conditions, irrigation, air quality, presence of pests). Drones (or unmanned aerial vehicles) equipped with sensors are also increasingly used for crop scouting and spraying. Drones can cover sizeable areas (including those that are difficult to access) in a relatively short time and take high-quality images, providing near real-time snapshots of the farm at a relatively low cost compared to satellite imagery, which is also used in some cases. Data captured by *in situ* sensors, drones and satellites allow better monitoring of crop health, assessment of soil quality, and optimisation of input use.

The introduction of robots is another trend in farming. Fruit-picking, harvesting and milking are examples of the repetitive and standardised tasks performed by agricultural robots. Although they are generally in the early stages of development, these robots are expected to increase efficiency and allow for more automated and precise agricultural practices.

Large agricultural machinery producers and input suppliers are taking advantage of the large amounts of data collected with IoT farm applications and robots, combined with other data (e.g. weather, market data), using them to develop “smart farming” services. Big data analytics and AI are employed to inform farm-management decision making (Wolfert et al., 2017). For instance, these systems can help the farmer decide when to plant or harvest their yields, choose the type of crop to plant depending on soil conditions and market prices, and automatically give instructions to agriculture robots to perform certain tasks. The expansion of precision and smart farming is still restricted mainly to large producers, given the large investments required for the deployment of such systems.

In the agri-food supply chain, the IoT, deploying sensors and actuators connected to software systems, has also begun to be used to trace products’ origins and track their trajectory as well as their transportation and storage conditions, improving the value chain’s transparency. Blockchain and other distributed ledger technologies (DLTs) are also expected to offer opportunities for increasing the traceability of food products from the origin to the point of sale (Tripoli and Schmidhuber, 2018, and see Donatelli and Pisante, 2019 for further insights on digital technology developments in the agri-food sector).

Automotive industry

Rapid digital technology developments are completely reshaping the automotive sector. These include vehicle innovations (e.g. car connectivity, autonomous driving), innovations

in production (with smart factories or Industry 4.0 applications), and new business models (with the provision of after-sales services and expansion into on-demand mobility services).

Digital technology has given rise to connected cars that generate data from the physical world, receive and process data, and connect to other cars and devices. Connected cars allow for enhanced driver safety and convenience, with services such as automatic emergency calls after an accident, real-time road hazard warnings to drivers, car repair diagnostics, systems of networked parking that reduce time for that chore, and navigation systems that optimise route planning by taking into account real-time traffic conditions.

Developments in autonomous driving are propelled by advances in the fields of robotics, artificial intelligence, machine learning and connectivity. There are different levels of automation. All new car models currently offer driving assistance systems, which take over parts of the vehicle motion control and support the driver with certain tasks such as parking and speed-keeping – but the driver is still in charge of driving. From a technical viewpoint, current systems for highly automated driving in controlled environments are quite mature (VDA, 2015). With full automation, cars drive independently and react to their environment without intervention from the driver. Such systems are currently being tested in pilot projects (PSC/CAR, 2017), but opinions differ greatly on when full automation might be achieved.

The automotive industry is also a leader in developing “smart factories”, adopting a variety of Industry 4.0 applications, including Internet-connected robotics, data analytics and cloud and high-performance computing, among others. Kern and Wolff (2019) provide examples of investments made by carmakers and automotive suppliers to maintain efficiency and further develop automation of their production and supply chain processes.

Automotive industry players are also providing new services related to their products (the “servitisation of manufacturing”, explored in Chapter 1). Three areas of focus are the provision of new after-sales services (e.g. predictive maintenance); development of alternatives to car ownership (e.g. vehicle subscription services); and expansion into on-demand mobility services, with the creation of their own car-sharing brands.

New platform-based on-demand mobility services (car sharing and ride hailing) are rapidly upscaling in a context of widespread access to personal mobile devices, and are becoming an attractive alternative to car ownership, especially for urban dwellers. Initially developed by new market entrants (e.g. Zipcar, Uber), they are now attracting investments from carmakers and automotive suppliers. Car sharing allows members access through a mobile app to vehicles owned by car-sharing companies as part of a shared fleet. Members typically pay an initial or yearly membership fee and usage fees by the mile, hour, or a combination of both.² Members of Zipcar, for example, can view all available vehicles around their location and book them by the hour (Zipcar, 2018). Ride-hailing platforms, such as Uber, allow matching real-time requests for rides with available drivers, speeding up the dispatch task and leading to greater utilisation of the vehicles (OECD/ITF, 2016).

² This differentiates car sharing from peer-to-peer car rental, which refers to the process whereby car owners rent their cars to other individuals for short periods through online platforms such as GetAround, Drivy and Turo. It also differs from traditional concepts of car rental, as the pick-up and returning points of car sharing vehicles are not limited to a few locations, such as airports or the offices of car rental companies.

The retail sector

In the field of retail, digital innovations aim at enhancing the consumer experience (in both physical and online shopping) and optimising processes (e.g. logistics, warehouse management). The largest investments focus on data collection (e.g. purchasing and browsing data) and data analytics capabilities. Such data provide insights on consumer needs and preferences that are used to customise the shopping experience, for instance by sending personalised advertisements and promotions.

Innovations in physical stores include smart dressing rooms, where customers can order the colour and size of the product of choice via a screen in the fitting room and receive personalised recommendations based on previous selection of items; digital mirrors that enable customers to easily try clothes on virtually using augmented reality systems; and automatic payment systems that allow customers to skip check-out lines. An example is the cashier-free AmazonGo store recently established in Seattle, enabled by the deployment of sensors, cameras and other digital technologies that allow for automatic payment of products that customers take off the shelf, without the need of scanning bar codes (Amazon, 2018). Innovations in online retail include applications that allow designing or personalising a product (e.g. shoes) through 3D visualisations. The automatic reordering of products may also become more common; the Amazon Dash Replenishment Service already allows connected devices (e.g. washing machines, coffee machines) to reorder products automatically (e.g. laundry detergent, coffee beans) when supplies are running low. All these innovations, however, remain marginal and are mainly deployed by large retailers.

The retail sector is also using IoT and robotics to better manage their inventories (e.g. in warehouses) and optimise other processes. AI is also opening avenues for predictive analytics to strengthen forecasting, improving the management of stocks. Drones and autonomous vehicles may also offer new possibilities for products' delivery in the future.

2.2. Digital technology opportunities for innovation: present and future

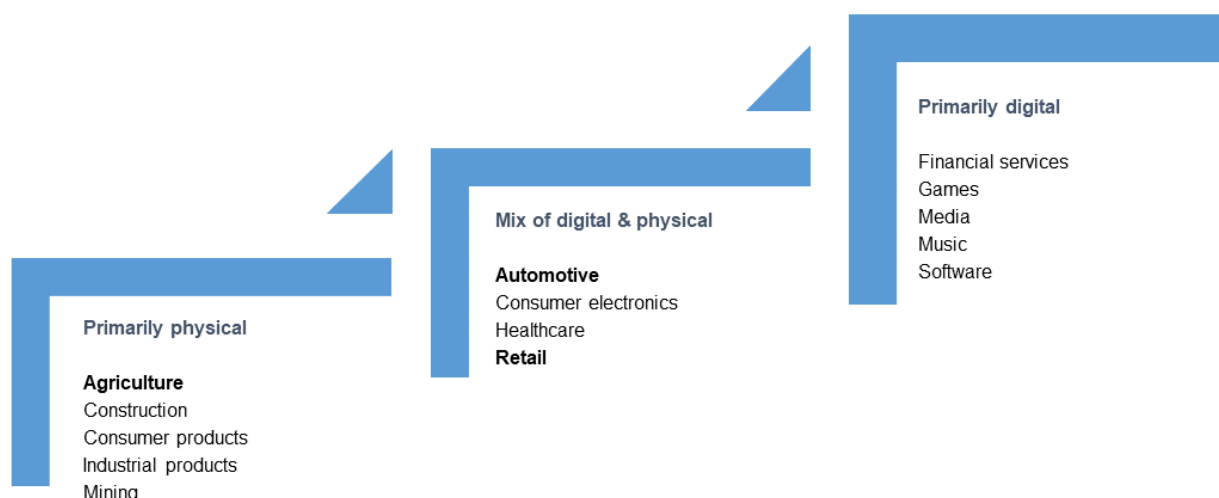
Future technology developments are inherently uncertain – yet given the important variety in the nature of sectors' products and processes, it is reasonable to expect that some sectors will be more disrupted by specific digital technologies than others, and that the transformation will take different forms and develop at different speeds.

Depending on sectoral characteristics, digital technologies may offer different opportunities to sectors for 1) digitalising their final products and services; 2) digitalising their business processes; and 3) creating new digitally enabled business models and markets.

(1) Opportunities for digitalising final products and services

Digital technologies have the potential to create new or expand existing goods and services with digital features – yet possibilities in this regard depend on the characteristics of specific sectors' end products. Some products are digital by nature. Those in the media, music and gaming industries, for instance, have been completely digitised over the past decades (Figure 2.2).

Figure 2.2. Opportunities to digitalise end products



Many industries have a mix of digital and physical components in their final products, with the digital ones often becoming progressively more important. The automotive industry is an example: vehicles increasingly integrate digital features, such as advanced infotainment systems and other functionalities enabled by connectivity and data analytics, and these are becoming key considerations in consumers' purchasing decisions.

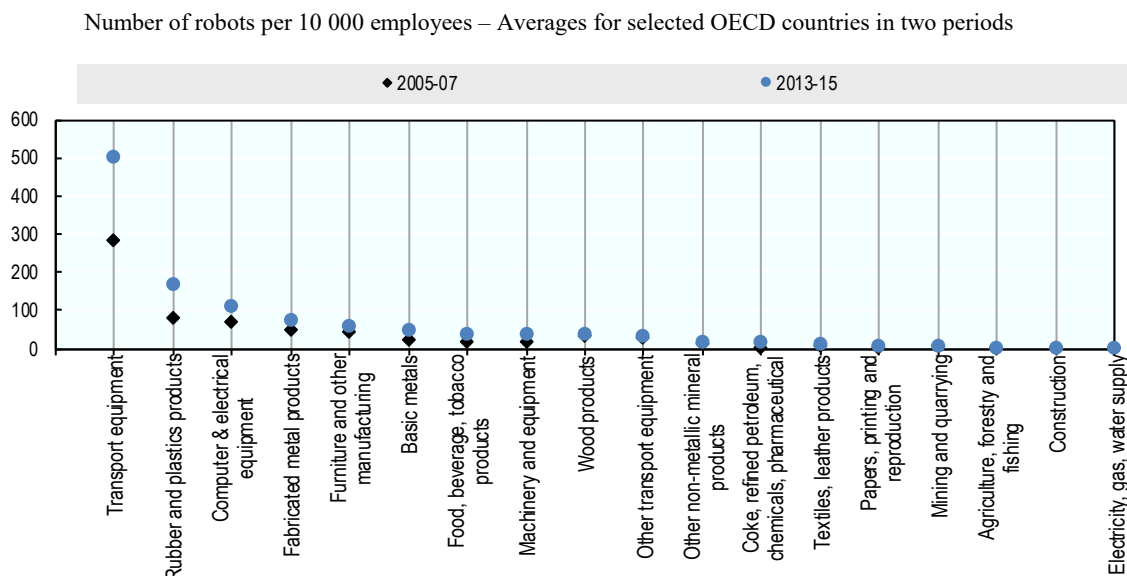
Other end products remain mainly physical, such as food and consumer products – but even those may, to a lesser extent, be progressively enhanced by digital features. In agriculture, digital technologies may foster the product value by offering IoT-based tracking systems that allow consumers to trace the origins and processing stages of the food they purchase. Such systems are however still in very early stages of development.

(2) Opportunities for digitalising processes

The extent to which sectors' business processes are affected by digitalisation may also be different, depending on the nature of the activities and the characteristics of production (e.g. whether it involves the assembly of physical products, if the sector is characterised by long supply chains, etc.). In particular, digital technologies offer opportunities for digitalisation (and automation) of production processes; for interconnecting supply chains; and for improving interactions with the final consumer. The relevance of these opportunities varies by sector.

Some sectors have highly automated production processes. The automotive industry is leader in the adoption of more advanced industrial robots, as shown by its high rate of robot density compared to other industries (IFR, 2017) (Figure 2.3). While robots have begun to be present in other sectors (e.g. the use of fruit picking, harvesting and milking robots in agriculture, and robots used in retail warehouses to optimise space and drive cost savings), not all activities equally lend themselves to automation.

Figure 2.3. Robots stock per employee, by sector



Note: Sector-specific values are simple averages over the years (2005-07 and 2013-15) and across OECD countries for which sectoral data are available for both periods. Data on transport equipment have the largest country coverage, with data for 27 countries. Sector labels are based on the sector's ISIC rev.4, 2-digit classification.

Source: Calculations based on De Backer et al., 2018.

Digital technologies also offer opportunities to interconnect supply chains, increase transparency and agility, and facilitate end-to-end management of the production and distribution processes. Yet connected supply chains are advancing at different speeds both across and within sectors. For instance, while big retailers have largely digitalised their supply chain activities, a long tail of small and medium-sized retailers lags behind (McKinsey Global Institute, 2016a). Developments are also unequal within the automotive sector (Kern and Wolff, 2019).

Some sectors also have more potential for using digital technologies to improve interactions with final customers. For instance, traditional retailers enter e-commerce to connect with consumers through new channels. The sector is also increasingly gathering data from end-consumers to personalise their offerings. This trend is less visible in sectors such as agriculture, even if a growing number of producers use digital technologies to directly connect to consumers, avoiding intermediaries.

(3) Opportunities for creating digitally enabled business models and markets

New markets or market segments enabled by digital technologies and adjacent to traditional sectors have been created over recent years. E-commerce, car-sharing services and financial technology (fintech) services are well-known examples. While new business models are emerging across the economy, the scale and disruption potential of these trends vary across sectors. In some cases the new models may largely displace traditional ones (e.g. online hotel searching platforms taking over an important segment of activity of traditional travel agencies), while in others they may co-exist and expand the product or service offering (e.g. brick-and-mortar existing simultaneously with online retail stores).

2.3. Data needs and challenges for innovation

Data have become a key input for innovation, as explored in Chapter 1. However, barriers to accessing that data also differ across sectors. For instance, the data needed for innovation in some are more sensitive than in others (such as patient data for healthcare innovations), or is less widely accessible. Data quality and the ease of integration of multiple databases, which is often needed for data to be relevant, may also differ across sectors. Some sectors may also be more attractive than others to digital talent, creating differences in the capacity to exploit data. Data ownership conditions may also be a barrier to innovation in some sectors. Unequal access to data across firms (and unequal capacities to exploit them) can create an uneven playing field among firms within the same sector, and lead to higher market concentration.

Table 2.1 presents some of the differences across the agri-food, automotive and retail sectors regarding the type of data needed for innovation purposes, and the opportunities and challenges related to those data types.

Precision agriculture services require large amounts of farming data, captured by a range of sensors (on the fields or mounted on machinery or drones) and satellites. To extract knowledge that informs farm decision making, integration of data from many farms is often needed, which poses important challenges. First, digital technology adoption in farming is still low, largely due to the necessarily high level of investment required. This makes it difficult to gather sufficient data to extract valuable knowledge. Second, there is an increasing resistance on the part of farmers to share data with big farm suppliers (often the actors providing these services). A lack of transparency regarding data analysis techniques and the specific algorithms used by these providers also raise concerns among farmers regarding possible biased analysis. Third, there are challenges linked to data quality (given the diversity of sources and actors collecting them) and the integration of such data (see Wolfert et al., 2017 for an in-depth analysis).

In retail, data are used to explore consumption patterns and personalise the shopping experience. To that end, retailers invest in gathering large amounts of consumer data (e.g. purchasing, online browsing and social media data). Extracting knowledge from those large datasets is technically complex and requires specialised data expertise, often difficult to access, particularly for small players. Data privacy and the ethical use of data are also growing concerns among consumers and policy makers.

Specific conditions also apply to other sectors. For instance, in healthcare the high sensitivity of data needed (personal patient data) requires ensuring data security and privacy, and access to data is often restricted. In addition, countries do not follow common standards in their collection practices, making data difficult to aggregate and exploit (see Auffray et al., 2016). There are also differences within countries with regard to the data collection practices that are applied by different hospitals, social security, private insurance companies, etc.

Table 2.1. **Data needs and challenges differ by sector**

	DATA NEEDS	MAIN CHALLENGES
Agriculture		
Precision agriculture	<i>Personal data:</i> - <i>Business data:</i> Aggregated sensor data from many farms / large-scale exploitation (captured by sensors on the fields or mounted on machinery or drones; satellite imagery) <i>Public & research data:</i> Satellite data (GIS, meteorological data, satellite imagery on crops)	- Low levels of digital technology adoption and high cost of uptake, particularly for small farms - Data sharing (resistance by farmers) - Data quality & integration - Building trusted data analytics
Product traceability in food supply chain	<i>Personal data:</i> - <i>Business data:</i> Sensor data collected by all members of the supply chain (incl. information on product's origin, processing stages and actors involved, transportation and storage conditions) <i>Public & research data:</i> -	- Engagement of the whole supply chain is required, but there are important differences in capacities for digital technology uptake across actors - Need for a clear definition of the type and amount of information to be shared - Data quality and integration
Automotive industry		
Connected cars	<i>Personal data:</i> - <i>Business data:</i> Historical data on cars performance (for predictive maintenance services) <i>Public & research data:</i> GIS, real-time traffic information	- Skills to exploit data - Data integration - Data privacy (risks e.g. usage-based insurance contracts) - Road safety (risk of cyber attacks)
Optimisation of value chain processes	<i>Personal data:</i> - <i>Business data:</i> Internal production and business processing data (for internal process optimisation); data on partners' processes (for value chain optimisation); real-time demand data <i>Public & research data:</i> -	- Skills to exploit data - Data quality and integration (data often siloed in different departments)
Retail		
Personalisation of consumer experience	<i>Personal data:</i> Customers & transactions data; personal data on social media and searching websites <i>Business data:</i> - <i>Public & research data:</i> -	- Skills to exploit data - Data integration - Personal data privacy (risk e.g. of price discrimination)
Optimisation of processes & inventory	<i>Personal data:</i> - <i>Business data:</i> Real-time in-store data (e.g. product stock, purchases); real-time online demand; data on inventory and internal processes <i>Public & research data:</i> -	- Skills to exploit data - Requires full digitalisation of processes

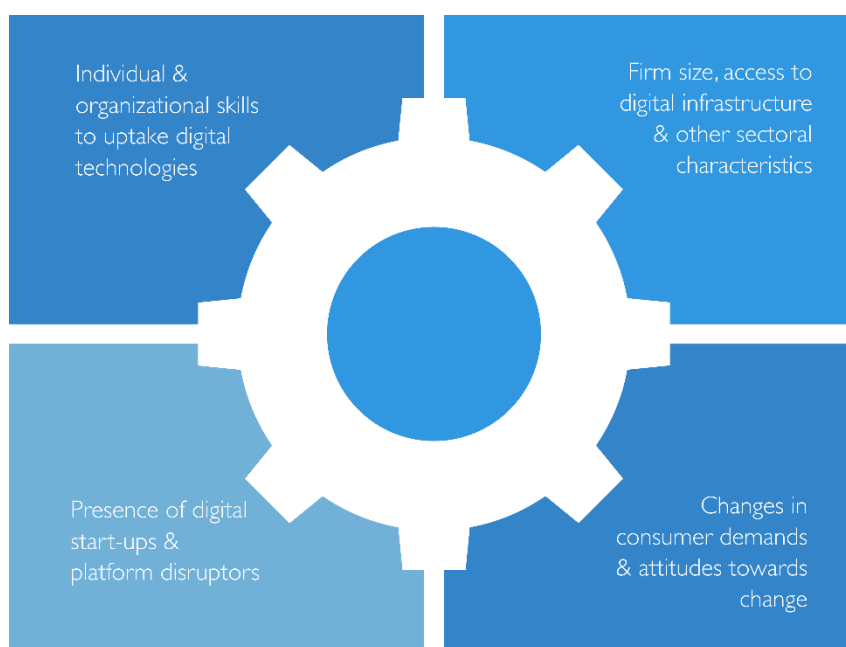
Source: Expert interviews; McKinsey Global Institute, 2016b.

2.4. Digital technology adoption and diffusion trends

The level of digital technology adoption varies across sectors (Calvino et al., 2018). Industry estimates show that, for instance, sectors such as automotive and financial services are currently leading AI adoption while others are falling behind, such as the tourism and construction sectors (McKinsey Global Institute, 2017).

Differences in adoption rates stem from variances in sectors' capabilities and incentives to adopt new technologies (Andrews, Nicoletti and Timiliotis, 2018). Key factors influencing adoption include: 1) capabilities to uptake new digital technologies; 2) presence of market disruptors; 3) specific sectoral characteristics and structures; and 4) consumer demands and attitudes towards change.

Figure 2.4. Key factors influencing digital technology diffusion and adoption across sectors



(1) Capabilities to uptake new digital technologies

Skills for adoption differ across sectors. Agriculture and construction for instance, characterised by the relatively high shares of low-skilled workers, register a low uptake. Capacities needed for digital technology adoption include skills at both the individual level (e.g. ICT skills, data expertise or previous related knowledge) and the organisational level. The latter go beyond “digital” skills and include among others the capacity to fine-tune organisational structures, adjust processes, redefine strategies and tasks, and manage emerging risks. Managers’ capacities to steer those changes and an organisational culture supportive of innovation and digital transformation are also critical for successful digital technology uptake.

Some sectors may also have more limited resources than others to build internal digital capabilities, invest in digital technologies, and promote a culture of innovation. In the case of agriculture, investments to deploy precision farming technologies or automate certain tasks are not affordable by family farms or small-scale exploitations, in a context of tight revenue models and high market competition that generate pressures for low food prices.

Disparities in terms of capacities and resources to take up new digital technologies contribute to increasing gaps in productivity performance across firms and sectors. This may lead to “dual economy” situations in the middle to long term, where innovative, technologically advanced and highly productive sectors or firms coexist with traditional, low-productive ones that benefit little from new technologies (Planes-Satorra and Paunov, 2017). For instance, the McKinsey Global Institute (2017) suggests that sectors that are leading AI adoption today are also those expected to invest more in AI in the future, leading to widening gaps between leading and laggard sectors over time.

(2) Presence of market disruptors

The emergence of new players in the market (i.e. digital start-ups or tech firms that enter existing markets or create new activities adjacent to traditional sectors) is pushing incumbents to innovate (McKinsey Global Institute, 2015). However, such pressures seem to be more critical in some sectors than others. For instance, in the automotive industry, the market entry of firms such as Alphabet (investing in the development of self-driving cars) and Zipcar (offering car-sharing services that transform the concept of mobility and potentially discourage car ownership) has significantly pushed carmakers to embrace new digital innovations. In agriculture, big machinery producers and input providers are heavily investing in developing software platforms for smart farming services and building strong capabilities in this area, so as to ensure they keep an advantaged position in the emerging smart farming market.

Some sectors are especially affected by the emergence of new platforms – be they platform marketplaces, platforms for the provision of on-demand services, etc. These can significantly change the competitive landscape. For example, two types of platforms are reshaping the tourism industry. On the one hand, platforms to search, compare and book accommodation and transportation options (e.g. Booking.com, Lastminute.com) lower the search and transaction costs of self-organising trips, disrupting traditional travel agencies. On the other hand, sharing economy platforms, such as Airbnb, provide for peer-to-peer accommodation services, whereby private owners can easily rent their spare rooms or properties. This puts competitive pressure on the hotel industry.

Impacts of market entry on innovation incentives may differ not only across sectors but also across firms. Some studies find that entry of new advanced players spurs innovation of incumbent firms at the technology frontier – as innovation is seen as the appropriate means to face the threat – while it discourages the innovation of laggards (Aghion et al., 2009; Czarnitzki, Etro and Kraft, 2014). The regulatory environment can also influence dynamics by determining what is allowed in terms of disruption.

(3) Sectoral characteristics

Sectoral characteristics also influence the pace of digital technology adoption, and particularly on how rapidly digital technologies permeate the activities of different types of actors (including SMEs, large firms, start-ups and research institutions) within the sector. These characteristics include:

- *The distribution of firm size and sectoral fragmentation* – Sectors characterised by firms of relatively large size may transition towards digital differently from sectors with a smaller average firm size. Large firms are usually early adopters of new technologies mainly due to higher resources to invest in new technologies and a higher technical expertise of workers (Zhu, Kraemer and Xu, 2006; Rogers, 2003). Small firms may, in addition of having fewer resources, be more risk-averse, as

failed investments could jeopardise their own survival. Yet large firms can also suffer from inertia, rigid hierarchical structures, and legacy systems that may hamper their transformation. Technology diffusion may also be slower in highly fragmented sectors, such as agriculture (with large numbers of individual farms) or health (with large numbers of hospitals and individual practitioners).

- *Access to relevant infrastructure* – The diffusion of digital technology strongly relies on access to critical infrastructure, such as broadband Internet connection and research infrastructures (e.g. R&D facilities, high performance computer centres). This may be a challenge for sectors and firms located in more remote or rural areas.
- *Complexity of supply chains* – Connections among firms along the supply chains also influence uptake dynamics. Firms integrated in global value chains may be more exposed to and have higher incentives to adopt digital technologies: suppliers may adjust more rapidly upon requests from upstream producers to adopt new practices, and receive support to implement them. For instance, Toyota supports its suppliers in implementing their new production systems (Kern and Wolff, 2019).
- *Level of public investments* – The public sector is the main (direct or indirect) provider of some services, such as education and healthcare. Thus the level of digital technology adoption largely depends on the capacity of the public sector to invest in those areas. While the uptake of readily available digital innovations in these fields can bring significant benefits, they often imply large public investments to ensure general adoption. Differing capacities to invest in and adopt those technologies may lead to cross-country differences in adoption rates.

(4) Consumer demands and attitudes towards change

Changes in consumer needs and demand are also driving the digital transformation of sectors, shaping differences in developments and applications. For example, in the field of transportation, consumer attitudes towards car ownership and use are changing, with the lower propensity of younger generations (especially in urban areas) to own cars and their preference for on-demand schemes. Consumers highly value the in-vehicle experience, with demands for higher customisation, user-friendly interfaces and seamless connectivity between cars and smart phones. In retail, consumers show increasing preference for personalised shopping experiences, online shopping and the quick delivery of products purchased on line. In agriculture, there is growing demand for new technologies that help reduce the environmental footprint and increase the efficiency of agricultural activities. Digital technologies can help reduce the use of inputs such as fertilisers, pesticides and water. They can moreover implement crop rotation and other agricultural methods that help mitigate soil erosion and reduce water consumption and pollution, ultimately reducing the impacts of agriculture on environmental degradation.

Resistance to change may also differ across sectors, depending on the awareness of opportunities offered by digital technologies; absorption capacities; and the state of development of sector-specific digital technology applications. Low levels of technology adoption may also be a reflection of consumers' resistance to change, which differs across products. For instance, there may be more resistance to accepting robots for personal care services than for new transportation services.

2.5. Differences within sectors

This chapter has focused on analysing the factors behind cross-sectoral heterogeneity in terms of digital innovation impacts. Within-sector heterogeneities also need to be considered however, as there are often striking gaps in the level of digital technology adoption and innovation capacity between leading and lagging players within the same sector across countries and regions; such has been illustrated by Russo (2019) in the automotive supply chain in Emilia Romagna (Italy). Such differences are often similar to factors leading to cross-sectoral variations.

Based on their analysis of the automotive supply chain, Kern and Wolff (2019) find the main factor behind differences in digital technology adoption is firm size rather than tier position (although a correlation between size and tier position does exist at lower tier positions). Multinational enterprises drive digitalisation forward as they are aware of emerging opportunities; already have certain infrastructure and employees with the right skills in place; and can afford to experiment with new technologies. Traditional SMEs perceive fewer benefits of the digital transformation – or even view them critically – and have fewer resources available. When pressures from customers to digitalise activities become too great, these firms decide whether to go ahead and invest in the necessary know-how and equipment, or readjust their customer portfolio and move to another line of business. Recent survey data on Industry 4.0 technology adoption in Italy also reflect that in manufacturing industries more generally, firm size remains an important predictor of propensity to adopt new digital technologies (Brancati, Brancati and Maresca, 2019).

In agriculture, important differences arise between large exploitations (e.g. in the United States and to a lesser extent in central Europe) and small ones (more predominant in southern Europe). Deployment of precision farming applications requires major investment and is only profitable if implemented in large exploitations where large amounts of data can be collected and exploited. As noted above, these applications are often not affordable for family farms or small-scale exploitations.

Differences across countries also play a major role. In developing countries, where agriculture (often subsistence agriculture) is typically a major economic activity, digital technologies are used (if at all) for more basic tasks, for example weather forecasting or other mobile phone applications to support farming. Digital technologies are also facilitating the provision of agricultural advisory services to farmers – previously too expensive or not accessible to producers in remote areas (Deichmann, Goyal and Mishra, 2016). App-based agricultural machinery sharing platforms are also emerging and help modest farms access machinery without acquiring it; MachineryLink Sharing and HelloTractor are examples.

Differences are also seen in retail. While big retailers have largely digitalised their supply chain activities and build on their data analytic capabilities to customise their offerings, there is a long tail of small and medium-sized retailers that lag behind and that have only very marginally changed their practices (McKinsey Global Institute, 2016a).

In addition to firm size and capabilities, the maturity of sector-specific digital technology applications also influences whether these are widely adopted by all players (and not exclusively by leading firms), as mature technologies are significantly less costly and involve lower investment risks (e.g. as they have already been tested in many other firms).

2.6. Conclusion

This chapter has explored the range of factors shaping the differences in impacts of digitalisation on innovation across sectors. These relate to differences in the opportunities for innovation offered by specific technologies; differences in data needs and challenges faced for innovation, and differences in digital technology adoption and diffusion patterns. There are also important differences within sectors across firms, regions and countries, reflecting large diversity in the impacts of the digital transformation across the world economy.

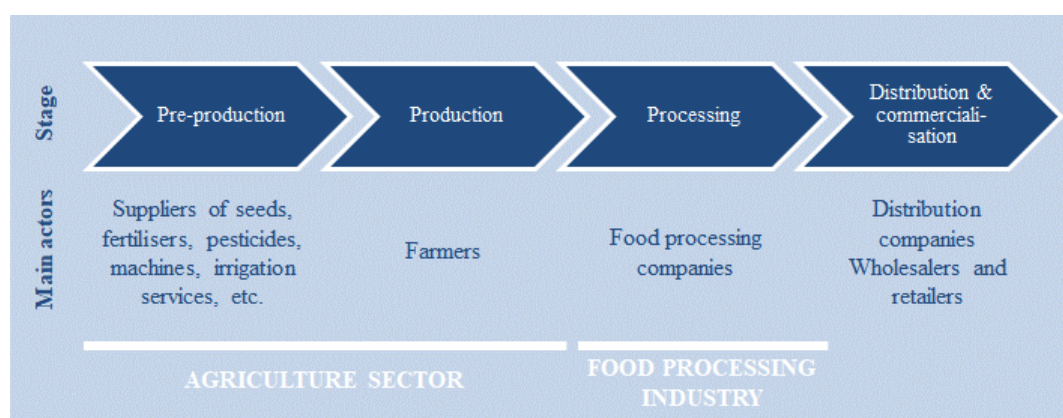
Future analysis would benefit from the creation of new databases gathering cross-country information on adoption rates of advanced digital technologies at firm level. Such data would allow measuring adoption trends across sectors but also across types of firms and locations, providing critical insights into current dynamics and the challenges for policy making.

Annex 2.A1. Definition of sectors covered in the report

Agri-food

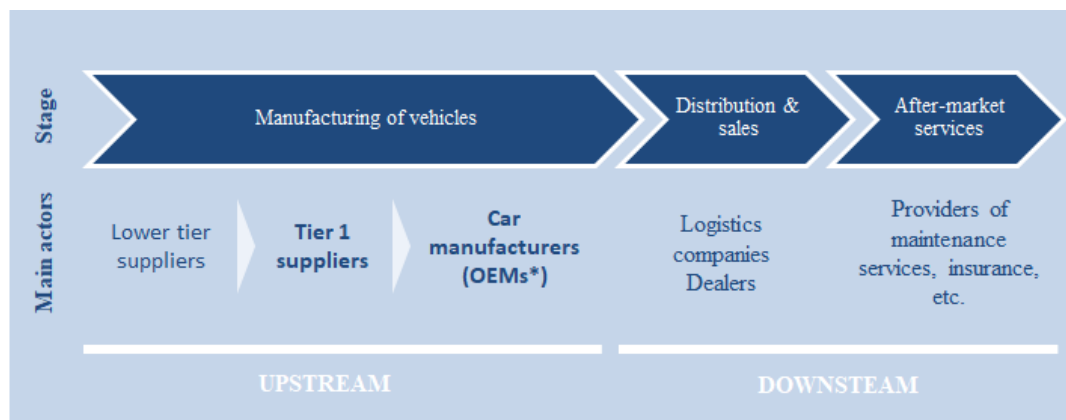
The agri-food sector comprises the production, processing, distribution and commercialisation of food. The report analyses the impacts of the digital transformation on innovation in the production stage of the agri-food value chain (Annex Figure 2.A1.1) (relating to the activities of the ISIC Rev.4 classification under Section A, Division 01, except for Group 017). The main actors traditionally involved in these activities are the producers (i.e. farmers), the manufacturers of agricultural equipment such as tractors, the suppliers of seeds, fertilisers and other inputs and services. The report also broadly covers the impacts of digital technologies on the food processing industry (Section C, Division 10), particularly regarding management of the agri-food supply chain.

Figure 2.A1.1. **Agri-food value chain: Stages and main actors**



Automotive and transportation sectors

Value chains in the automotive sector comprise the manufacturing, distribution and commercialisation of vehicles, as well as after-sales activities. The report explores the impacts of the digital transformation on the innovation activities of large car manufacturers (or automotive original equipment manufacturers, OEMs) and first-tier suppliers (i.e. direct suppliers of components and parts to OEMs) (Annex Figure 2.A1.2) (corresponding to the activities of the ISIC Rev.4 classification under Section C, Division 29). The report also covers road passenger transportation services in urban areas (corresponding to the activities under Section H, Division 49, Class 4922 of the ISIC Rev.4 classification).

Figure 2.A1.2. **Automotive value chain: Stages and main actors**

* Original equipment manufacturer

Retail

The retail sector involves the process of selling consumer goods or services to ultimate consumers, both on line and at physical stores (corresponding to the Section G, Division 47 of the ISIC Rev. 4 classification). It also includes retailers transporting products from warehouses to stores and directly to consumers. The report analyses impacts of the digital transformation on the innovation activities of large retailers.

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Chapter 3. How should innovation policies be adapted to the digital age?

This chapter explores how policy support for innovation should change in order to effectively promote vibrant and inclusive innovation ecosystems in the digital age. It explores directions for policy in terms of data access, entrepreneurship, public research, education and training, and ways to stimulate competitive, collaborative and inclusive innovation ecosystems. It concludes with guiding principles that should inform policy action and change: setting national policies in the context of global markets; engaging with the public to address technology-related public concerns; and taking sectoral perspectives on board in the design of innovation policies when needed.

Introduction

With broad and deep transformations in innovation under way with digitalisation, are existing innovation policies still relevant and efficient? Do they appropriately address emerging challenges?

This chapter explores how policy support for innovation should change so as to be effective in promoting vibrant and inclusive innovation ecosystems in the digital age.

The chapter finds that effective development of innovation will require governments to adopt policy mixes that respond to the changing landscape. The new policy mix should comprise five key objectives (Table 3.1):

1. Ensure access to data for innovation (Section 3.1).
2. Provide support and incentives to innovation and entrepreneurship (Section 3.2).
3. Build a strong public research system and a skilled labour force (Section 3.3).
4. Promote competitive, collaborative and inclusive innovation ecosystems (Section 3.4).
5. Set national policies that take account of the global context and citizens' concerns (Section 3.5).

The changes called for by the digital transformation affect the entire innovation policy spectrum, but to varying degrees across policy domains. Some domains need to adapt their target or content to digital innovation while essentially preserving their established processes; this includes for instance policies supporting entrepreneurship, digital technology adoption by SMEs and the development of general purpose technologies. Other domains need to go through in-depth reform, sometimes including a rethinking of the policy rationale: that includes public research policy (moving towards open science) and policies supporting science-industry knowledge transfer, moving towards knowledge co-creation.

A sectoral approach is also needed with regard to some policy areas, in particular data access policies, adoption and diffusion, and support for digital technology application development. The challenges and needs faced by sectors in these areas vary significantly, as explored in Chapter 2.

Innovation is also influenced by many policies that do not target it explicitly or primarily, such as education, tax, health, environment, transportation and competition policies. This last is particularly critical for innovation, as only the right competitive environment will stimulate firms to innovate and pursue innovation-driven growth, as explored in Chapter 1 (OECD, 2015a).

The focus here is on innovation policies per se. Broader policy questions are addressed by the OECD-wide horizontal Going Digital project, which has developed an integrated policy framework for making the transformation work for growth and well-being (OECD, forthcoming – a).

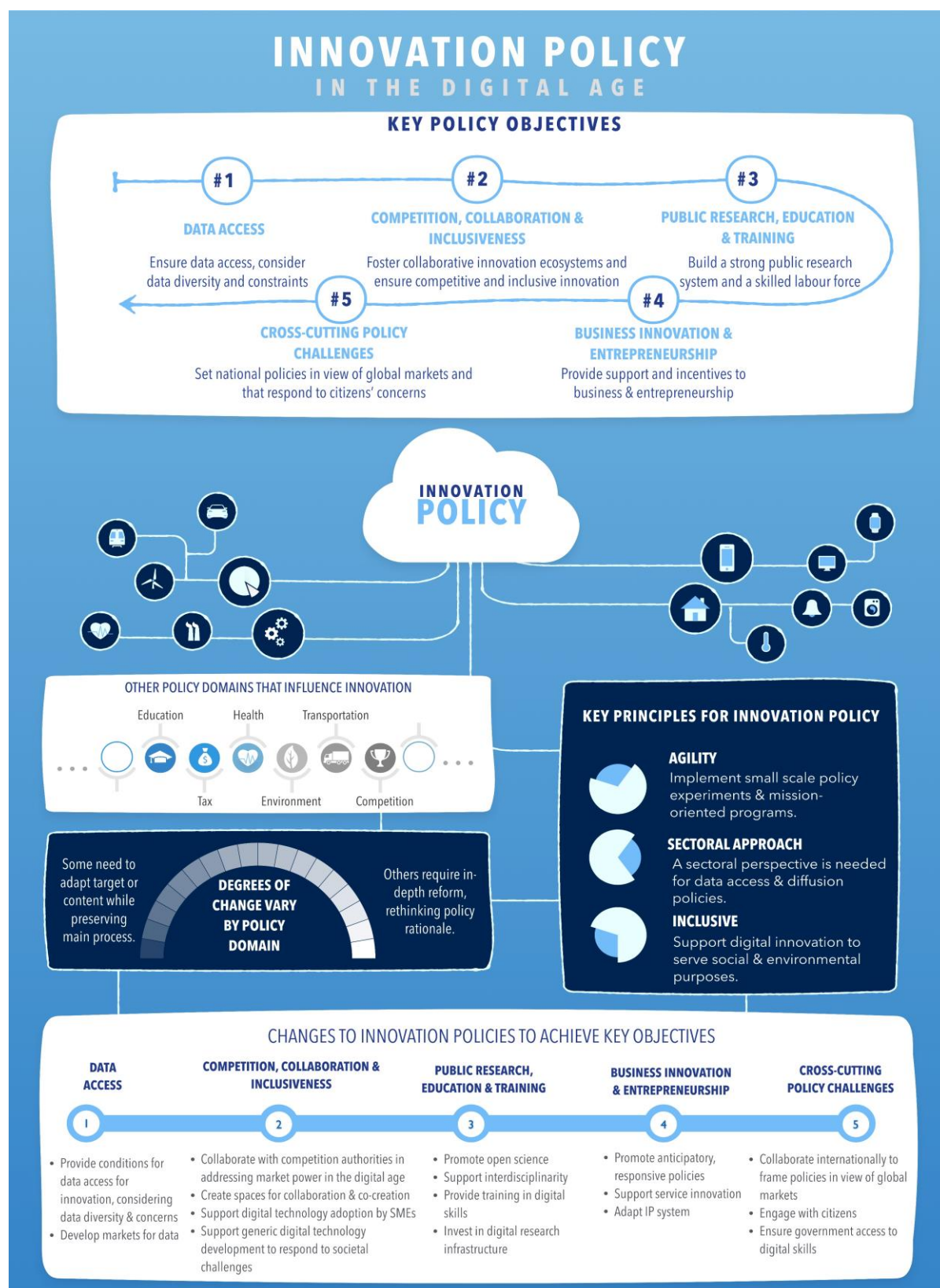
Table 3.1. Major changes to innovation policies called for by digitalisation, by policy domain

Policy domain	Change required
Access to data (Section 3.1)	– Ensure access to data for innovators, taking into account the diversity of data and preserving rights and incentives* – Explore possibilities for developing data markets
Business innovation and entrepreneurship (Section 3.2)	– Ensure that policies are anticipatory, responsive and agile – Support service innovation that implements digital technologies – Adapt the IP system – Support the development of generic (multi-purpose) digital technologies*
Public research, education and training (Section 3.3)	– Promote open science (access to data, publications) – Support interdisciplinarity – Support training in digital skills for science – Invest in digital infrastructure for science – Develop co-creation with industry – Ensure that the skills needed for digital innovation are being developed (in collaboration with education and labour market policy authorities) – Support education and training for the development of managerial skills
Competition, collaboration and inclusiveness (Section 3.4)	– Collaborate with competition authorities to review competition policies from the perspective of innovation in the digital age (e.g. rules regarding takeovers and standards; adaptation of IP systems) – Develop and promote collaborative innovation ecosystems – Support digital technology adoption by firms, particularly SMEs* – Support social and territorial inclusiveness in digital innovation activities
New cross-cutting policy challenges (Section 3.5)	– Frame national policies in view of global markets – Adopt a sectoral approach to policy making when necessary – Engage with citizens to address technology-related public concerns – Ensure government and public research access to skills and data

* These areas especially require taking a sectoral approach to innovation policy making.

This chapter is structured as follows. Sections 3.1 to 3.4 explore the changes needed with regard to data access policies; policies to support innovation and entrepreneurship; public research, education and training policies; and policies to stimulate competitive, collaborative and inclusive innovation ecosystems. Section 3.5 discusses the wider question of framing national policies in a context of global markets – adopting a sectoral approach to policy making when needed – and engaging with the public to address technology-related public concerns. Section 3.6 concludes.

Figure 3.1. Synthesis of chapter 3



3.1. Data access policies

Due to their fluidity, data have many properties of a public good (notably their non-rivalrous nature, as the same data can be used simultaneously by various actors). Hence they can be sources of market failures. As data now constitute primary inputs to innovation, access to data – and to the tools that gather and help interpret them – will influence who participates in digital innovation, and in what ways. It is therefore necessary to develop a specific policy agenda around data access (OECD, 2015b). There are two priority areas for policy action: first, ensuring access to data for innovation while taking into account data diversity; and second, exploring the development of markets for data.

Ensure access to data for innovation, taking into account data diversity

The main objective of data access policies should be to ensure the broadest possible access to data and knowledge to favour competition and innovation, while respecting constraints arising from data's diversity (access issues differ), trust (privacy, ethics, etc.), economics (incentives to produce the data, competition, intellectual property), and different national frameworks regarding data protection.

As data access issues differ, policy approaches to those issues also differ. Access to public research data allows reproducing and testing the validity of scientific research, and reusing it to conduct further research (OECD, 2015c; Dai, Shin and Smith, 2018). Some governments establish open access to data generated by public services (weather monitoring, urban transportation, etc.) in order to promote data-driven innovation. For instance, the open data portal in the United Kingdom (data.gov.uk) publishes data from the central government, local authorities and other public bodies that cover a variety of fields – from education and the environment to health and transport – in order to create new opportunities for organisations to build innovative digital goods and services. The online platform TransportAPI, which provides real-time country-wide information on departures and timetables as well as journey planning services covering all modes of transportation, was created using such data (TransportAPI, 2018).

Regarding private sector data, different criteria for access may be considered. Data that are core to firms' business could be (and in some countries are) treated as trade secrets. In the case of data generated by the core activity of a firm (e.g. data on the manufacturing and use of its products), opening access might hand critical information to competitors, which would be to the detriment of the firm. It could also allow competitors with higher data-processing skills to establish themselves as intermediaries between themselves and their customers, which may not always be conducive to innovation in these sectors. SMEs in particular may be challenged by large firms' uses of big data.

Explore the development of data markets

Government should also set up appropriate conditions for the emergence of markets for data. Trading data may not only facilitate their exchange for innovation purposes, but also allow putting a price tag on data generation and curation for future use – thus facilitating the generation of more data. Such markets also facilitate the entry of start-ups that do not hold such data but that require them to develop their business. Data marketplaces could allow trading raw data on digital platforms as well as data that are normalised and standardised so as to facilitate their immediate application. Moreover, there are opportunities for data aggregators and quality assurers that provide access to bundles of data that have been verified and validated (Deichmann et al., 2016).

There are major challenges to developing knowledge markets. Issues relate notably to the specificity of data (data are often adapted to a specific context, out of which they may have little or no value), which limits their transferability. Informational and appropriability difficulties, as well as difficulties in evaluating the true market value of data and the quality of such data, pose further challenges. There are also privacy and safety aspects affecting personal data – anonymising data is increasingly impossible – and justified questions about their tradeability by data aggregators.

Some of the obstacles to the development of data markets may be mitigated with new digital tools. First, the Internet (platforms) and AI could help tackle the informational issue (i.e. improve the ability to locate data that respond to a specific need by using better search tools, powered by AI). Second, blockchain (an Internet-based public ledger) may help strengthen appropriation by tracing data ownership and uses.

Government action here should be informed by close monitoring of the changes induced by technology and the economy. Government should consider using data markets for public sector data; they should also ensure that the IP system is amenable to those transactions. Government is also responsible for handling certain non-economic issues, such as privacy and integrity; if these are not appropriately addressed, they will block transactions (which require reliability and trust).

3.2. Policies to support innovation and entrepreneurship

Specific directions of change for innovation and research instruments that arise from the characterisation provided in the previous sections include 1) making innovation policies anticipatory, responsive and agile; 2) ensuring support for service innovation; 3) adapting the patent and IP system to the digital economy; and 4) providing support for the development of generic (multi-purpose) technologies.

Ensure that policies are anticipatory, responsive and agile

The new instruments needed for the digital age should be quick and agile. Government needs to become more flexible and reactive, while keeping (prudential) rules of engagement when it comes to specific policy instruments. The innovation agenda is shifting very quickly and is difficult to predict in certain fields.

Approaches to ensure rapid and agile policy responsiveness include the following:

- *Conduct policy experiments* – Experiments in a “start-up mode” can be deployed and then evaluated to establish whether they should be modified, scaled up or down, or abandoned quickly. Implementing various alternative policy approaches on a small scale and combining them with close and frequent monitoring to identify what works and what does not also helps learning.
- *Use digital tools to design and monitor innovation policy* – This can help make decision making more quick and effective, on the basis of stronger evidence. For example, semantic analysis can support innovation policy making by exploring large quantities of text data (e.g. innovation policy documents, patents, scientific articles) to identify policy trends and anticipate emerging technology trends (See examples discussed at a recent workshop in OECD, 2018a).
- *Accelerate procedures for application-based innovation support instruments* – This helps increase the responsiveness of such policy instruments. For example, the Pass French Tech programme provides start-ups in a hyper-growth stage with simplified

and quick access to services (e.g. in the fields of financing, access to new markets, innovation, business development) to help them with their expansion (La French Tech, 2018).

- *Support instruments that do not target specific technologies or recipients* – Such instruments avoid making technology choices, and include tax reliefs, some regulations, and IP rights. The drawbacks of such instruments as compared with targeted ones such as grants and loans for innovation (e.g. lack of selectivity resulting in a deadweight loss) need to be taken into account and weighted against the advantage of greater flexibility.
- *Support mission-oriented programmes that set a goal but do not impose the means to reach it* – Such an approach avoids supporting obsolete technologies, and provides more autonomy and agility to choose the proper technological avenues to achieve a stated policy objective; such is the case with the Defense Advanced Research Projects Agency (DARPA) in the United States (Azoulay et al., 2018). Similar programmes have been adopted by other countries, including Canada, to spur game-changing technological breakthroughs.
- *Establish public institutions that connect to technology* – Where making choices on specific technologies cannot be avoided – as for instance with public procurement involving specific requirements such as data security – designing public institutions connected to technology developments in the private sectors can help governments be better informed about latest technology developments, as well as their potential benefits and harmful impacts. Data61 in Australia and Digital Catapult in the United Kingdom are examples.
- *Favour anticipatory regulation* – Regulation-setting standards also need to be agile, to allow for innovation while avoiding detrimental effects. This is important because problems raised by new products (e.g. regarding safety or security) are often difficult to anticipate before their commercialisation. According to some, fast-paced technical change requires outcomes-focused regulation. That is to say, there are no rules as to what is and what is not allowed; instead, the desired outcomes and main principles are established in order to prevent public harm – so-called “anticipatory regulation”. This approach requires scanning future potential threats and risks around a new technology or activity, as performed by the UK Food Standards Agency and the UK Human Fertilisation and Embryology Authority (Armstrong and Rae, 2017).

Access to skills in different areas of technology development is critical for governments to provide appropriate research and innovation policy support. Access is at risk however, notably in the area of AI, as salaries for experts are so high that government and academia cannot afford them. While government funding has been supporting AI research for decades, funding is now largely undertaken by businesses as governments can ill afford the huge costs of research and retaining the top researchers.

The fact that businesses are active in the field is certainly positive, but government’s weakening position raises important issues. Who will fund the basic research needed to sustain progress in the field, as there are limits to the willingness of businesses to generate spillovers that also serve their competitors? How can government design and monitor the implementation of societal principles (regarding ethics, accountability, etc.) if it cannot hire top-level experts? Government’s access to skills is particularly critical because the design of regulation and policies requires an in-depth understanding of the technologies at stake.

This concern might also extend beyond access to skills, and include access to data and information systems. A large share of data relevant to innovation policies is privately owned, and data-gathering infrastructures are increasingly based on the Internet, with some controlled by businesses. This is the case for instance with databases of scientific publications, used to compile indicators that feed into government's monitoring and policy processes. Access conditions to these data should allow government to preserve its proper policy capacity.

It is vital that government keeps its ability to act, and to act in an independent way. For that, it needs to ensure that wages in the public sector remain sufficient to draw enough workers with high-level skills in digital technologies, notably AI.

Support service innovation that implements digital technologies

Supporting services innovation requires using instruments different from those commonly used for innovation support. Many innovation policies have been conceived for manufacturing innovation, which is R&D-intensive, results in patents, etc. Service-type innovation (e.g. new business models) relies very little on R&D, and thus may not be eligible for policy support (such as R&D tax incentives). However, service innovation requires business to have a deep understanding of digital technologies that is not yet widespread, especially among SMEs in non-digital industries.

Initiatives may include supporting R&D projects aimed at developing new services using new digital technologies (e.g. the Smart and Digital Services Initiative in Austria), or support to manufacturing SMEs that will help them develop services related to their products (e.g. service design vouchers for manufacturing SMEs in the Netherlands).

Adapt the IP system

The IP system is aimed at encouraging the creation of new ideas, be they technological or commercial. The current system has been designed for tangible inventions, embodied in physical products and processes. With digitalisation, the system is confronted with new questions that require policy responses. These include in particular:

- *Incentives for data generation* – Access to data is often optimal for society, and there is a clear move towards open data systems. Yet incentives to produce data may call for some exclusivity. How should the IP system adapt?
- *Patentable inventions generated by AI* – This raises the question of who should own them – the original programmer, the user of the software that generated the invention, or the owners of the data to which AI is applied? In addition, patent grants require that the invention be “non-obvious to a person skilled in the art”. If an AI system is considered to be such a person skilled in the art, this might place the bar much higher for patentability in certain domains (e.g. combinatorial chemistry) where AI is now a major research tool.
- *Changing risks of counterfeiting* – The ease with which intangible product components can be diffused increases the risks of counterfeiting. Certain developments, such as 3D printing, may allow for new forms of manufacturing, weakening IP protection. Digital technologies such as blockchain can facilitate enforcement of protection by making it possible to trace the uses of particular data files, and so limit online counterfeiting. Blockchain-enhanced intellectual property rights covering a range of intangibles (e.g. photographs, music, movies) may be a

way forward to create a more easily enforceable and tradeable intellectual property rights (IPR) for the intangible economy.

- *Changes in IP uses* – IPR, and patents in particular, may become much less relevant and weaken the incentives they provide in this new environment. With digital innovation, control – of standards and of data – becomes much more important. Trademarks may, however, take on renewed importance as anchors for online search (Bechtold and Tucker, 2014).

Support the development of generic digital technologies

Policy should support the development of generic (or multi-purpose) digital technologies, with a view to facilitating downstream innovation and to address societal challenges. Businesses are investing heavily in these technologies now, but initial developments were most often sponsored by government. This was the case of AI, developed almost exclusively through publicly funded research over more than five decades before being seized on by businesses in the late 2000s. Hence government needs to keep investing in generic technologies so as to prepare future waves of innovations.

Governments also need to ensure that the development of multi-purpose digital technologies serves not only commercial purposes but also social and environmental ones. In many cases, public research is the best placed to do that. Those investments benefit from co-creation, i.e. collaboration in technology development, and from developing a shared vision around the economic, ethical, policy and legal implications of AI. The Artificial Intelligence Forum in New Zealand and the Learning Systems Platform in Germany, for example, bring together innovators and representatives from industry, academia, government and society to discuss the technological and socio-economic challenges of AI (including ethical concerns), and jointly develop roadmaps to shape the future impacts of AI on the economy and society.

3.3. Public research, education and training policies

Just as digital technologies hold the promise of increasing the efficiency of innovative activities, they also have the potential to increase research efficiency in various ways. The most noted potential – one that applies across all disciplines including the humanities – consists of exploiting data and machine learning techniques to support the research process. Other avenues include the involvement of non-experts in the research process (“citizen science”), including by “gamification” of research challenges that attract crowds of amateurs to experiment (see e.g. the famous “Foldit” game, which consists in predicting the structure of proteins). Researchers from academia are increasingly adopting these new approaches, enabled by the Internet and other information technologies.

Avenues for preparing public research for the challenges of the digital age include the following four domains (in addition to open science, discussed in Section 3.1):

- *Supporting interdisciplinarity* (particularly combining computer sciences with specific traditional disciplines). For instance, many universities currently offer interdisciplinary undergraduate degrees with a digital component (e.g. MIT undergraduate degrees on computer science and biology, and on computer science, economics and data science) (MIT, 2018).
- *Offering specific training and capacity-building activities for scientists to master digital tools* (data curation, simulation, deep learning, etc.). Even scientists that do

not apply digital tools personally should be sufficiently familiar with them to be able to collaborate with other scientists applying them. Strengthening researchers' digital skills is one of the key objectives of the digitalisation strategy for the higher education sector in Norway (2017-21) (Government of Norway, 2018).

- *Developing and investing in digital tools and infrastructures that are critical for research* (e.g. platforms for sharing data, supercomputing facilities for AI, etc.). An example is the High Performance Computing Infrastructure (HPCI) programme in Japan, involving an annual investment of more than USD 120 million to build a high-performance computing infrastructure that is accessible to universities and public research centres for R&D purposes in a range of fields.
- *Engaging in partnerships and creating “spaces” for co-creation with industry* to draw on industry progress in advanced digital technologies for their applications in research, and on digital capacities in industry and science, moving knowledge transfer from science to industry or vice versa.

Preparing individuals for the digital transformation is essential to ensure their participation in most dynamic economic activities, a critical factor for their future well-being. It is also necessary in order to respond to industry needs for skilled workers able to perform emerging jobs and tasks in the digital economy. The education policy domain is critical to innovation but is of course far broader, touching on many other policy dimensions. The OECD-wide Going Digital project looks into this question in depth (OECD, 2017a; Nedelkoska and Quintini, 2018). Innovation policy authorities have a critical role to play here, in two main areas.

First, they should collaborate with those in charge of education and labour market policies to ensure that the right skills needed for digital innovation are being developed – in formal education systems, vocational training and lifelong training. New combinations of skills required by industry in the new context should be taken into account. For instance, innovation in the automotive industry increasingly requires strong capabilities in software engineering and AI, in addition to traditional core competencies in mechanical and electronic engineering. An example of a co-ordinated approach is the National Initiative on Digital Competences 2030 in Portugal (INCoDe.2030), which aims to generalise digital literacy to ensure social inclusion, stimulate employability and professional specialisation in digital technologies, and enhance the production of new knowledge in digital areas (FCT, 2018).

Second, innovation authorities should support training and education in digital competences and skills for managers as well as civil servants. Management skills are clearly important for firm performance, particularly in a context of disruptive technological change (Bloom and van Reenen, 2007). For public services and policy making to benefit from digital technologies – and for policies to appropriately address the challenges and complexities that characterise the digital age – it is also critical to provide training to civil servants and policy makers on digital skills as well as dynamics in their direct and indirect domains of policy work.

3.4. Policies to develop competitive, collaborative and inclusive innovation ecosystems

Digital innovation is changing market dynamics. As explored in Chapter 1, the fluidity of data and the emergence of digital platforms can, on the one hand, foster market entry and competition, while on the other lead to market concentration, with distributional

implications. This can call into question the fundamentals of competition policy (OECD, 2016, 2017b, 2018b). For instance, it is difficult to determine exactly what constitutes a “dominant position”, as market positions are constantly threatened by new entrants. Arguably, digital innovation requires firms to be large, in order to achieve economies of scale; weakening dominant firms (e.g. through aggressive anti-trust action) could therefore weaken innovation. On the other hand, several small firms and regulators have claimed that large companies engage in behaviour (e.g. product tie-ins or preventive takeovers) that may hamper competition and innovation, as they prevent small players from accessing the market.

Policies that support competition, together with policies fostering collaboration and inclusive innovation, would help support the long tail of firms that are not innovation leaders (particularly SMEs) and regions (including rural areas with limited innovation capacities). Innovation policy can play a critical role by: 1) engaging with competition authorities in considering whether competition policies need to adjust; 2) supporting collaboration for innovation; 3) providing support for digital technology diffusion and adoption by firms; and 4) implementing innovation policies that foster social and territorial inclusiveness.

Promote competitive innovation ecosystems

Dialogue between competition authorities and innovation policy makers will be needed to address a range of questions – notably regarding the use of data as a source of market power, as well as the contestability of markets for digital innovation. Such markets are subject both to rapid innovation (a source of contestability) and various sorts of scale economies (a source of persistent concentration) (see Chapter 1 and Guellec and Paunov, 2018). New policies should recognise the importance and prevalence of economies of scale, while ensuring equal access to markets and resources. As competition on digital markets takes place at a global level, there may also be a need for greater co-operation across jurisdictions (OECD, forthcoming – b; Tirole, 2019).

It is also necessary to reflect on whether innovation policy instruments and regulations (e.g. support for R&D, IPR) have an asymmetric impact on market players. While such instruments are accessible to all in principle, this may not be the case in practice, e.g. as regards the capacity of firms to defend their IP rights in courts, to collaborate effectively with public labs, or to access public procurement. Thus, considerations of how policies can best support entrepreneurship and entry will also be important.

Support collaboration for innovation

The relevance for innovation of collaboration among firms and universities, research institutions and in some cases individual inventors is not specific to digital innovation, but collaboration is certainly taking on greater importance in the digital context (see OECD, 2019). The reduced cost of collaboration stemming from digitalisation has not reduced all barriers to it (such as differing regulatory regimes and diverging incentives). Thus policy will have to continue supporting collaborative innovative ecosystems and consider new forms of collaboration towards innovation, such as data sharing, crowdsourcing, and platforms for co-creation.

Policy approaches already implemented to foster collaborative innovation include creating platforms and forums for different actors to collaboratively design roadmaps and participate in strategic planning (e.g. Platform Industry 4.0 in Austria); supporting knowledge intermediaries (e.g. Fraunhofer Institutes in Germany or Catapult Centres in the

United Kingdom); and establishing collaborative research and innovation centres (e.g. Data61 in Australia and the Manufacturing USA programme). Some countries are also using cluster policies (e.g. the Innovation Superclusters Initiative in Canada) and conditional grants for collaborative R&D and innovation projects (e.g. MADE Digital in Denmark). Chapter 4 provides a review of innovative policy approaches to support collaborative innovation.

Support digital technology adoption by firms, particularly SMEs

Firms (particularly SMEs) face important challenges in adapting to the digital transformation. Adaptation requires much more than simply purchasing new computers and software: it is about changing business processes, and often business models. This often entails new strategic capabilities, new skills, investments in new technologies and significant restructuring, all of which can be risky. The disappearance of many SMEs that fail to digitalise would mean the loss of much industry and market-specific know-how, which constitutes unique intangible capital.

Government can implement various instruments to support digital technology adoption. Support services should be tailored to the specific needs of the sector and/or type of actor. These may include awareness-raising schemes, training and education, demonstration of new digital technologies, and the creation of intermediary institutions to connect suppliers with potential users of new technologies. Innovative policy approaches to support digital technology diffusion are explored in detail in Chapter 4.

Support social and territorial inclusiveness

Innovation policies have a role to play in enhancing the participation of disadvantaged individuals in innovation activities. Some groups have traditionally been underrepresented in research and innovation activities (e.g. women, ethnic minorities, residents in deprived areas) – a trend that may be exacerbated in the context of digital transformation. Given the diverse skills and profiles needed for innovation, drawing on the potential of these groups becomes all the more important. Policy instruments to address social inclusiveness challenges include those aimed at building capacities (e.g. entrepreneurship education); at addressing discrimination and stereotypes (e.g. awareness-raising activities, role models and mentoring programmes); and at addressing barriers to entrepreneurship (e.g. facilitating disadvantaged groups' access to finance through microcredit or equity financing, providing tailored business development support, and promoting their insertion into business and research networks). Some countries have already implemented “inclusive innovation policies”. Examples include targeted grants for research projects led by researchers from disadvantaged groups in South Africa; a programme to improve the research environment for women in Japan; and initiatives to support the entrepreneurship of minority communities in Israel. Planes-Satorra and Paunov (2019) provide more inclusive innovation policy examples.

Regulatory action is also needed to ensure that digital innovation itself does not create or exacerbate inclusiveness challenges. Examples include AI-based decision-making tools that replicate current forms of social exclusion (such as the racial biases found in predictive algorithms used to inform judges' decisions) and data-profiling techniques that discriminate against some groups when it comes to certain services (e.g. banks' use of social media and other personal data to determine the credit rating of clients). Digital innovations may also benefit some individuals more than others (e.g. human-machine interaction interfaces that cannot be used by blind individuals).

Increasing concentration of innovation activities in innovation hotspots (often urban areas) also calls for the implementation of policies favouring territorial inclusiveness. “Excellence-based policies”, even if blind to location, tend to favour geographical concentration since excellence is concentrated (due notably to knowledge spillovers), indirectly contributing to widening the gap between leading and lagging regions. Excellence-based policies should therefore be complemented by policies favouring geographical inclusiveness and diversity. The focus should be on promoting innovation at the local/regional level, building on specific regional strengths and comparative assets (e.g. the Smart Specialisation approach in the European Union).

3.5. Principles for innovation policies in the digital age

The following principles are critical for innovation policy to best support innovation activities: 1) setting national policies in the context of global markets; 2) engaging with citizens to address technology-related public concerns; and 3) taking sectoral perspectives when designing innovation policies when needed.

Set national policies in the context of global markets

Digitalisation facilitates circulation of knowledge – including across national borders, which reduces governments’ ability to restrict the benefits of policies to their own country. That presents a challenge for national policy makers: how can they ensure that their own citizens (and taxpayers) benefit from national policies, and that most of the benefits (e.g. income generated, productivity gains or job creations) do not leak abroad? The question has been raised in the past, in the context of basic research funding and business R&D support measures. Cases of successful start-ups having benefited from government support then being acquired by foreign multinationals have raised questions about the location of the benefits arising from these start-ups. There is also a risk of “walled gardens” if policies become highly nationalistic in focus.

Along the same lines, there are questions about the sharing of benefits generated by exploitation of national data (e.g. from the public health system) with foreign multinationals. The embodiment of value in intangible assets (intellectual property), the intangible character of digital products transacted across borders, and the prevalence of electronic payments all facilitate the circulation of revenue, which can end up in tax havens. How government will address the issue of territoriality will have a strong influence on the efficiency of policies, but also on their legitimacy. Co-operative solutions will be needed that allow a sharing among countries of the benefits arising from international flows of data and knowledge linked to national policies. OECD activity on base erosion and profit shifting (BEPS) is a step in this direction (www.oecd.org/tax/beps/).

Engage with citizens to address technology-related public concerns

Public acceptance of new technologies is another key area of innovation policy. The digital transformation has captured much attention in the press and among the public – sometimes with negative views, for instance regarding leakages of personal data and the threat of robots taking over jobs. This may significantly increase mistrust of and resistance to new digital technologies. To address public concerns, it is important that governments and the scientific community engage with the public in order to increase evidence-based awareness about the opportunities, risks and impacts of digital technologies, and that these are appropriately considered in policy making. In this context, it is critical that the advice of institutions and science is seen as trustworthy and unbiased, and that public policy produces

a response to emerging public concerns (e.g. by enhancing data privacy protection, supporting the development of applications for the public good). Consultations with the public during the development of digital transformation strategies and other related policies can help increase trust (Winickoff, 2017). The risk of not engaging is to be confronted at some point in the future with a significant backlash, which could have negative impacts on the development and deployment of these technologies and their related benefits (OECD, 2015c; Dai, Shin and Smith, 2018).

Adopting a sectoral approach to policy making when necessary

Some policy domains require taking a sectoral approach when designing new initiatives, as the challenges and needs faced by sectors in certain areas vary significantly, as explored in Chapter 2. Such an approach becomes particularly relevant in three policy areas.

First, data access policies should consider the diversity of data types used in different sectors (see Table 2.1 in Chapter 2); that diversity signals significant differences in terms of challenges associated with their generation, access and exploitation.

Second, digital technology adoption and diffusion policies should be tailored to the capabilities of the sector and/or type of actor, and address challenges that may be sector-specific (e.g. ensuring access to basic infrastructure such as broadband in the case of agriculture). Chapter 4 provides more details on policy initiatives that have been implemented by countries to further digital technology adoption.

Third, support for developing sectoral applications of general purpose digital technologies will be important for diffusing benefits across the economy.

Designing the proper tailored support to sectors operating in the digital context requires, as a first step, establishing mechanisms to strengthen “policy intelligence”. Such mechanisms may include developing roadmaps or sectoral plans for key strategic sectors in the country, in collaboration with industry stakeholders and social partners. These plans would set out the long-term vision for the sector, the current challenges and opportunities facing it, and the actions needed to address them. In Australia Sector Competitiveness Plans, developed by six sector-specific Industry Growth Centres in consultation with stakeholders, aim to inform both policy making and the science and research community about industry knowledge needs and technology gaps, and suggest a range of regulatory reforms. Such plans are annually revised to account for new sector developments (Australian Government, 2017). Sector Deals in the United Kingdom follow a similar approach (GOV.UK, 2017). Examples in the automotive sector include the Austrian Research, Development & Innovation Roadmap for Automated Vehicles (Affenzeller et al., 2016) and the Dutch HTSM Roadmap Automotive 2018-25 (Wouters et al., 2017).

Countries are also engaging in foresight exercises to explore long-term policy challenges linked to the digital transformation. These exercises involve the development of different scenarios by the government working jointly with stakeholders from industry and academia, and are used to promote dialogue and jointly identify long-term policy challenges as well as regulatory barriers and enablers for the diffusion of digital technologies. In Australia for instance, Data61 – in partnership with the Department of Industry, Innovation and Science (DIIS) – has developed foresight scenarios to explore how digital innovation might transform the country’s businesses and economy in the next decade (Quezada et al., 2017).

3.6. Conclusion

This chapter has explored the main innovation policy domains needing changes. These span the whole innovation policy spectrum. Some domains need to adapt their target or content to digital innovation while essentially preserving their processes; this includes for instance policies supporting entrepreneurship, digital technology adoption by SMEs and the development of general-purpose technologies. Other domains need to go through in-depth transformation, such as in the areas of public research and collaboration. Access to data has also become a major new theme in all policy domains relating to innovation (e.g. public research and competition), and has become a policy domain itself.

In some policy domains (e.g. data access, competition), the way forward is still very much in debate. In those cases, this chapter has provided a number of principles for policy guidance rather than strong recommendations, as the latter largely depend on the country and sectoral context.

Many countries are already implementing the changes explored in this chapter. Innovative approaches implemented to encourage collaboration for innovation and digital technology diffusion and adoption are explored in detail in Chapter 4.

Other domains that are beyond the scope of this report but have an impact on innovation include education and training policies, norms and standards, competition and labour market policies, and regulations. Those areas are addressed by different strands of work undertaken in the OECD Going Digital project.

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Chapter 4. Policies to stimulate digital innovation's diffusion and collaboration

This chapter gives an overview of novel policy approaches recently implemented in different OECD countries to support digital technology adoption across the economy, including demonstration facilities for SMEs, test beds and regulatory sandboxes. It also discusses innovation policies aimed at encouraging collaborative innovation in the digital age, such as the creation of platforms for strategic planning, collaboration research and innovation centres, crowdsourcing initiatives and living labs. The chapter also presents traditional instruments used to support technology adoption (e.g. awareness-raising schemes, technical support) and collaborative innovation (e.g. cluster policies, the creation of networks) that are being revisited by countries to address the challenges of the digital age.

Introduction

The digital transformation features prominently in national science, technology and innovation policy agendas, as part of main STI strategies or as dedicated national digital strategies, Industry 4.0 strategies or AI strategies. Moreover, many governments are experimenting with novel innovation policy approaches and instruments to facilitate a successful and inclusive digital transformation of their economy. Important priorities include promoting digital technology adoption and diffusion, and making collaborative innovation – defined as innovation among different actors, including large firms, start-ups, SMEs and public research organisations – more effective.

This chapter looks at some of the innovative approaches undertaken in OECD countries, with the focus on digital technology adoption and diffusion and efforts to promote the development of collaborative innovation.

The chapter shows that many experimental policy approaches to promote diffusion centre on facilitating the testing of new digital technology applications, for instance by creating test beds and regulatory sandboxes. Innovative initiatives are also implemented to enhance early adoption of advanced digital technologies by facilitating innovators' access to state-of-the-art facilities and expertise (e.g. in the fields of AI and supercomputing). Traditional instruments to foster technology adoption by SMEs – such as awareness-raising campaigns, innovation vouchers, technical assistance and training – have been revisited to respond to specific challenges of the digital age, and often make use of opportunities offered by digital tools themselves.

Innovative instruments are also used to spur collaborative innovation. Most experimental approaches include the use of crowdsourcing and open challenges, as well as the creation of living labs, to find novel solutions to pressing challenges and promote co-creation. Intermediary organisations, such as Catapult Centres in the United Kingdom, have become central players in innovation ecosystems, providing services such as matching firms needing technology solutions with potential suppliers. New research and innovation centres, often public-private partnerships, have also been created to provide spaces for multidisciplinary teams of public researchers and businesses to work together to address specific technology challenges. These often stand out for their innovative organisational structures. Examples include Data61 in Australia and Smart Industry Fieldlabs in the Netherlands. Traditional instruments such as cluster policies, the creation of networks, and provision of financial support continue to be implemented but are used in new ways.

This chapter builds on a number of country policy case studies contributed to the OECD TIP Working Party's Digital and Open Innovation project (see Annex 4.A1). It also incorporates information from country responses to the 2018 European Commission/OECD Science, Technology and Innovation Policy Survey and the 2017 OECD Digital Economy Outlook questionnaire. A wider policy collection exercise, covering other innovation policy domains, is presented in Planes-Satorra and Paunov (2019).

The chapter is structured as follows. Section 4.1 presents fresh initiatives implemented to stimulate digital technology adoption and diffusion. Section 4.2 presents equally original initiatives to promote collaborative innovation. Section 4.3 concludes, and Annex 4.A1 provides an overview of the policy case studies contributed by countries to the OECD TIP Working Party's Digital and Open Innovation project.

4.1. Supporting digital technology adoption and diffusion

New digital technologies are developing quickly, but do not diffuse evenly across the economy. Well-known challenges that have affected technology adoption in the past and remain relevant at present – such as lack of information, skills, expertise, resources or trust in new technologies – contribute to widening productivity gaps between leading and lagging firms in the digital era, with negative impacts on well-being and growth. Initiatives supporting economy-wide diffusion and adoption of digital technologies thus become the backbone of innovation policy mixes aimed at promoting inclusive innovation-led growth (i.e. where all actors can participate in and benefit from digital innovation).

Governments are experimenting with novel policy approaches to furthering digital technology adoption and diffusion. These initiatives aim in particular at facilitating: 1) awareness raising and capacity building; 2) digital technology investments; 3) the demonstration and testing of new technologies; and 4) access to the most advanced technologies, such as AI. The first two mostly target SMEs, while the last two mainly target innovative entrepreneurs and start-ups. In addition, some initiatives combine several of these instruments, which are discussed below. For instance, German SME 4.0 Competence Centres provide awareness raising and training about digitalisation, opportunities to access demonstrations of new technologies, and opportunities for networking.

(1) Awareness raising and capacity building

Awareness-raising schemes are deployed in many countries to inform firms and entrepreneurs about the opportunities that digital technologies offer. An innovative approach that builds on digital technologies themselves is the availability on line of virtual maps developed by France, Germany and Japan, which display domestic SMEs in different sectors engaged in Industry 4.0 transformations. Such maps allow sharing first-hand experiences of the benefits and challenges faced by firms, and how these were addressed. The objective here is to inspire similar firms to engage in the digital transformation by diffusing lessons learned across firms and sectors (Alliance Industrie du Futur, 2016; Plattform Industrie 4.0, 2015; Robot Revolution Initiative, 2016).

Such schemes are typically accompanied by more tailored, often sector-specific support to enhance businesses' capacities to successfully adopt digital technologies. In Chile, the Digital Extension Centre provides technical assistance to SMEs in the agri-food sector that aims to improve their competitiveness by digitalising production processes. Support consists of assessing the firm's capabilities, identifying the best digital technology solutions for each case, and helping deploy the solutions and ensure their best use (Bravo, 2019). The SME Digital programme in Austria provides tailored education and training to strengthen the digital skills of SMEs (BMDW, 2018). The CAP'TRONIC programme in France provides technical seminars, training, counselling services and expert support to help SMEs employ digital solutions and embed software in their products (CAP'TRONIC, 2017).

Many traditional policy instruments are used in new ways. This includes innovation vouchers – small non-repayable grants provided to SMEs to purchase services from public knowledge providers that will help introduce small-scale innovations. For instance, the trading online voucher scheme in Ireland assists SMEs in developing their e-commerce capabilities, providing up to EUR 2 500 matched by their own funding (DCCAE, 2018). Service design vouchers for manufacturing SMEs in the Netherlands are an experimental scheme to help these SMEs develop services related to their products, so as to remain competitive in a context of increasing “servitisation of manufacturing” (RVO, 2018). In

Wallonia (Belgium), the vouchers for digital transformation cover between 50% and 75% of the cost of advisory services aimed at auditing the digital maturity and needs of SMEs and then designing a tailored action plan (Chèques entreprises, 2018).

(2) Financial support for digital technology investments

Governments have established financial support mechanisms to help cover often large-scale infrastructure investments needed for SMEs to fully engage in the digital transformation. In Korea, the SMEs Programme for Smart Manufacturing helps SMEs modernise their production facilities by financing up to 50% of the costs of digital technology adoption. France has established the Digital Loan scheme to help finance corporate investments for the introduction of digital technologies in firms. Loans range between EUR 200 000 and EUR 3 million, and need to be matched with at least equivalent co-funding, to be reimbursed over seven years (Bpifrance, 2018).

(3) Demonstration and testing of new digital technologies

Some countries have established new facilities to demonstrate digital technologies, as a means of increasing adoption. For instance, the SME 4.0 Competence Centres in Germany offer SMEs access to demonstrations of Industry 4.0 technologies and sector-specific applications (e.g. 3D printing, sensors). These demonstration facilities are often located at universities and allow simulating business and production processes in a real-world environment (BMW I, 2019).

Countries are especially exploring novel approaches to supporting testing of and experimentation with new digital technology developments and applications. These take different forms:

- *Testing facilities* – The Industry Platform 4 FVG, established in the Italian region of Friuli-Venezia Giulia, offers access to testing equipment, prototyping tools and demonstration labs (Salvador, 2019). Pilot factories have also been set up in several Austrian universities (TU Wien, TU Graz and Johannes Kepler University Linz), where SMEs have the chance to test new technologies and production processes without having to affect production in their facilities (Mattauch, 2017). The Labs Network Industrie 4.0 is a private sector initiative that provides German SMEs with access to test centres, where they can try out their new technologies, innovations and business models and review them prior to their market launch. They also facilitate the process of standardising validated results (LNI4.0, 2016).
- *Test beds* – Testing environments (or test beds), where new technology developments can be tested in controlled but near to real-world conditions, are critical for research and innovation in areas such as autonomous driving, and allow accelerating the adoption of new digital technologies. In Finland, a number of test beds are being established for the open development of transport and mobility solutions, including automated driving, mobility-as-a-service, and intelligent traffic infrastructures (Team Finland, 2017). Many other countries have established (or are currently in the process of establishing) testing grounds for self-driving vehicles, including Austria (ALP.Lab, DigiTrans), Germany (A9 Digitale Autobahn) and Sweden (AstraZero) (BMBWF, MBVIT and BMDW, 2018).

In the United Kingdom, a Test Beds Programme was introduced in 2016 by the National Health Service (NHS) in partnership with industry. Such test beds allow testing innovations (e.g. combinations of new digital devices such as sensors,

monitors, wearables with data analysis) and new approaches to service delivery facilitated by digital technologies, with the objective of assessing their efficiency and identifying action needed to improve them. Successful innovations are then made available to the NHS and care organisations around the country. There are currently five health and care test beds and two IoT test beds. In view of successful outcomes, a second wave of test beds has been launched (NHS England, 2018).

- *Regulatory sandboxes* – These provide a limited form of regulatory waiver, or flexibility for firms to test new products or business models with reduced regulatory requirements, while preserving some safeguards (e.g. to ensure appropriate consumer protection) [see [DSTI/CDEP/GD/RD\(2018\)1](#)]. Sandboxes help identify and better respond to regulatory breaches, and enhance regulatory flexibility. They are particularly relevant in highly regulated industries, such as financial services (OECD, 2018), transport (ITF, 2015), energy (OECD/IEA, 2017) and health (OECD, 2017).

The Financial Conduct Authority in the United Kingdom pioneered this approach with the launch of the fintech regulatory sandbox to encourage innovation in the field of financial technology. The sandbox provides the conditions for businesses to test innovative products and services in a controlled environment without incurring the regulatory consequences of pilot projects (FCA, 2015). Other fintech sandboxes were created in Australia, Canada, Hong Kong, Malaysia and Singapore. In the energy sector, the British Office of Gas and Energy Markets created their Innovation Link service, a “one stop shop” offering rapid advice on energy regulation to businesses looking to launch new products or business models. When regulatory barriers prevent launching a product or service that would benefit consumers, a regulatory sandbox can be granted to enable a trial (Ofgem, 2018). The Energy Market Authority in Singapore also launched a regulatory sandbox to foster innovation in the energy sector (EMA, 2018).

(4) Access to most advanced technologies and expertise

Some interesting initiatives – such as projects launched by Digital Catapult in the United Kingdom – aim to facilitate early adoption of advanced digital technologies and ensure innovators’ access to state-of-the-art facilities. These target the most innovative firms (e.g. small, digital start-ups) and aim at helping them realise their opportunities to innovate in new areas and to be able to compete with larger, global organisations.

Digital Catapult has several such initiatives in place. One is the Dimension Studio, aimed at ensuring that UK businesses have access to volumetric capture technology, which is expected to drive the next generation of immersive experiences and products. Another is the Machine Intelligence Garage programme, which helps businesses access the computation power and expertise they need to develop and build machine learning and AI solutions (Digital Catapult, 2019).

In some EU Member States, High Performance Computing (HPC) centres have been set up in connection with the Supercomputing Expertise for SME Network programme to facilitate access by industry (especially SMEs) to HPC expertise. The programme also helps disseminate best practices in HPC industrial use (SESAME Net, 2018).

4.2. Spurring collaborative innovation

The relevance to innovation of collaboration among firms and universities, research institutions and in some cases individual inventors is not specific to digital innovation, but collaboration is certainly taking on greater importance in a digital context (see OECD, 2019). The reduced cost of collaboration stemming from digitalisation has not reduced the barriers to collaborating, such as differing regulatory regimes and diverging incentives. Furthermore, with accelerated technological change, rapidly translating research findings into innovative goods and services becomes critical. Policy thus needs to continue supporting innovative ecosystems, and consider new forms of collaboration towards innovation, such as data sharing, crowdsourcing and co-creation.

The innovative policy approaches and instruments to support collaborative innovation ecosystems presented in this section are: 1) platforms and forums for strategic planning; 2) collaboration facilitators, including intermediary organisations, networks and clusters; 3) collaborative research and innovation centres; 4) crowdsourcing, open challenges and living labs; and 5) financial support for collaborative R&D.

(1) Platforms and forums for strategic planning

A number of governments, often jointly with industry, have recently established new platforms or forums to encourage different stakeholders to collaboratively design roadmaps and engage in strategic planning regarding the digital transformation, in specific sectors or the economy as a whole. Such platforms encourage debates around the economic and social impacts of digital innovation, and aim both to create a shared vision and to provide balanced policy and industry recommendations or action plans.

The Platform Industry 4.0 in Austria is an example. It gathers actors from industry and science, regional and national policy makers, associations, trade unions and NGOs to balance interests between actors, accompany the processes of change driven by the digital transformation, and provide knowledge and services on Industry 4.0 to companies, academia, research organisations and to the general public. It defines the fields of action and provides advice to Austrian policy makers to develop joint strategies to fully benefit from Industry 4.0 (Boog et al., 2019). Similar examples include Plattform Industrie 4.0 in Germany, the Industrial Value Chain Initiative in Japan, and the Platform for Digital Transformation in Industry in Turkey

Some forums focus on specific technologies or sectors; this is the case with the Artificial Intelligence Forum in New Zealand. Launched in 2017, the forum brings together AI-related technology innovators, investor groups, businesses, entrepreneurs, academia and government to identify and support AI opportunities in New Zealand. It engages in research that provides insights and information to lead the debate about the opportunities, challenges and potential impacts of AI in the country. Its latest report, entitled “Artificial Intelligence: Shaping a Future in New Zealand” includes a range of policy recommendations (AI Forum, 2018). A similar example is the Learning Systems Platform in Germany (Lernende Systeme, 2018).

(2) Collaboration facilitators: intermediaries, networks and clusters

Intermediary organisations

Intermediary organisations connect different actors in innovation ecosystems (innovators, big firms, SMEs, investors, etc.) and facilitate their matching and collaboration for research and innovation. The Catapult Centres in the United Kingdom are a network of ten not-for-profit, independent physical centres that connect businesses with the country's research and academic communities. Each of them focuses on a strategic technology area in which the United Kingdom has great potential for growth. They offer a space with the facilities and expertise to enable businesses and researchers to collaboratively solve key problems and develop new products and services on a commercial scale. They also help businesses access foreign markets, create and retain high-value jobs, and attract inward investments from global technology businesses (Digital Catapult, 2019). Industry Growth Centres in Australia also aim to build stronger industry systems through collaborative, industry-led processes. The six independent, non-for-profit centres focus on increasing collaboration and commercialisation of innovations in specific sectors, and on improving access to global supply chains and international opportunities (Australian Government, 2018).

Networks

Some countries provide support for creating innovation networks that promote interaction and collaboration among actors within and across sectors. The Knowledge Transfer Network, established by Innovative UK, helps linking companies across industries to solve problems and find markets for new ideas, while facilitating access to technical knowledge and innovation capabilities. It also facilitates access to UK and EU calls for public funding that require collaboration among different stakeholders. In 2017, the network organised more than 400 events involving over 20 000 participants (Knowledge Transfer Network, 2018).

Digital platforms also facilitate the creation of networks to boost industry-research collaborations. Public research and universities can advertise their inventions, knowledge and capacities, and businesses can post their own needs. The two sides can then interact and agree on deals. Such platforms support small-scale entrepreneurs in particular, by offering them opportunities to identify adequate niche markets. For example, Expert Connect is a searchable database created by Data61 in Australia, which contains profiles of over 45 000 research and engineering experts from Australian research organisations (Data61, 2018, 2019).

Clusters

Some of the new initiatives take a territorial approach. Their objective is to promote partnerships for research and innovation among regional actors in a specific manufacturing sector or technology area; to enhance their competitiveness at the national and international levels; and to ensure science-industry knowledge transfer. For instance, the French Cluster for Digital Transformation (Cap Digital) in Paris gathers innovative SMEs, research and higher education institutions and firms in digital industries. It forges links and promotes collaborative research among them, and provides members with training and funding for R&D projects, among others (Cap Digital, 2018).

The Estonian ICT Cluster promotes co-operation among businesses in the ICT and other sectors, to develop new products and solutions. The cluster supports businesses in three areas: internationalisation (e.g. organising business visits and export-related activities, joining international innovation projects); workforce development (e.g. providing training, forecasting the skill needs of the workforce); and co-operation (e.g. supporting research activities among cluster partners and helping to find external partners) (Estonian Clusters, 2018). Other examples include the Innovation Superclusters Initiative in Canada, the Digital Hub Initiative in Germany, the Cluster Intelligent Factories in Lombardy (Italy), and the Digital Hub in Dublin, Ireland).

(3) Collaborative research and innovation centres

Several countries have created (networks of) research centres where multi-disciplinary teams of public researchers and businesses work together to address specific technology challenges. These not only provide new spaces for collaboration and co-creation, but also stand out for their innovative organisational structures, often in line with innovative business practices that implement agile methods and create start-up-like environments.

Data61 (CSIRO) is the largest digital R&D centre in Australia. Its mission is to put Australia at the forefront of data-driven innovation, both by pursuing new-to-the-world fundamental and applied research, and by working collaboratively with other actors in the nation's innovation ecosystem. It has four axes of collaboration:

- collaborations with other CSIRO business units to provide multi-disciplinary R&D and data science expertise across domains
- collaborations with universities through research partnerships, agreements on strategic joint appointments, and co-funding of PhD students
- collaboration with government in the area of digital service transformation and policy analytics – particularly in the field of open data, acting as trusted advisor and providing technology development, contract R&D assistance and strategic guidance
- collaboration with industry to convert ideas into data-driven businesses, including programmes targeted at SMEs and start-ups, such as in the area of technology licensing, R&D partnerships, innovation accelerators, and access to expertise.

To increase agility and attract digital talent, Data61 has adopted a “start-up culture” or “market pull” approach: organisational structures are flatter (i.e. with less middle management and higher autonomy of staff) and research leaders are encouraged to experiment with new ideas and to take risks while maintaining full alignment with the strategic goals of the organisation. A “challenge model” also has been introduced to stimulate multidisciplinary teams to address large-scale social and business challenges. Another innovative feature is Data61's mixed funding model, aimed at balancing public and commercial sources of funding to ensure that the organisation does not become a “work-for-hire” (consultancy-type) entity. The objective is to attract profitable, high-margin revenues to provide additional capacity to do self-directed fundamental and strategic research (Data61, 2019).

Smart Industry Fieldlabs in the Netherlands are public-private partnerships for creating physical or digital spaces for member companies and research institutions to jointly develop, test and implement new smart industry technological solutions (e.g. in the fields of automation, zero defect manufacturing, flexible production, value creation based on big

data, 3D printing and robotics). The 32 current Fieldlabs typically include users of such solutions, (potential) suppliers and knowledge institutes, and are active in collaborative research, concept validation, prototyping, testing and validation. Fieldlabs ensure an interdisciplinary approach and link research to domains where the Netherlands has specific strengths. They do not have hierarchical structures and follow a project-based approach (Stolwijk and Punter, 2019).

The Manufacturing USA programme has established manufacturing innovation institutes across the United States. Within each institute, manufacturers of all sizes partner with academia and government to share and solve industry-relevant advanced manufacturing technology and workforce challenges, and to build a robust, sustainable national manufacturing R&D infrastructure so as to enhance industrial competitiveness and economic growth. Each institute has a unique technological concentration and is designed to be a public-private membership organisation that provides vision, leadership and resources to its members. Industry, academia and government partners are benefiting from existing resources, collaborating, and co-investing to nurture manufacturing innovation and accelerate commercialisation (AMNPO, 2018). Other examples include Flanders Make in Belgium, the Technology Centres Programme in Ireland, and the Technology Competence Centres in Estonia (see Planes-Satorra and Paunov, 2019).

(4) Crowdsourcing, open challenges and living labs

In line with the business trend towards open innovation practices (explored in Chapter 2), governments are also exploiting mechanisms such as crowdsourcing, open challenges and living labs to find innovative solutions to pressing challenges and to nurture co-creation. Citizenscience.gov is an initiative designed by the US Government to accelerate the use of crowdsourcing so as to engage the public in addressing social needs and to accelerate innovation. The website also provides a Crowdsourcing and Citizen Science Toolkit that shows how to plan, design and carry out a crowdsourcing or citizen science project, and showcases a number of case studies (CitizenScience.gov, 2018).

Open challenges are also increasingly used to encourage innovation. For example, the Social Challenges Innovation Platform (created with EU Horizon 2020 programme funding) encourages social innovators and entrepreneurs to propose innovative solutions to social and environmental challenges that public authorities, private firms or NGOs aim to solve, and that post in the platform (SocialChallenges.eu, 2018). Pit Stop events, organised by Digital Catapult (United Kingdom), encourage open innovation by bringing together large firms, SMEs, start-ups and academics to solve specific technology challenges. Disruptive technology start-ups and other actors able to solve such challenges are identified via online open calls (Digital Catapult, 2018, 2019).

Living labs are defined as “user-centred, open innovation ecosystems, integrating research and innovation processes in real life communities and settings” (ENoLL, 2018). They are localised areas of experimentation within urban environments, in which stakeholders collaboratively develop new technology-enabled solutions. Smart Kalasatama in Helsinki is an example of a living lab that has achieved high citizen engagement in the co-creation of new urban services enabled by digital technologies and data (Mustonen, 2016). In Antwerp (Belgium), a “City of Things” is being developed through installation of a dense network of smart sensors and wireless gateways in buildings, streets and objects. Collected data can be used by companies to build innovative smart applications (Department of Economics, Science and Innovation, 2017).

(5) Financial support for collaborative R&D

Other instruments used to encourage collaboration include conditional grants for collaborative R&D and innovation projects, such as the MADE Digital initiative in Denmark. Stimulating research collaboration is also one of the key objectives of the Research-Create-Innovate programme in Greece, which provides grants for research and innovation in key areas in which ICT technologies are key enablers, to strengthen the country's competitiveness (Gongolidis, 2018). The Industrial Strategy Challenge Fund in the United Kingdom supports science-industry collaboration to jointly find solutions to major societal, environmental and industrial challenges identified by the government together with industry and academia (GOV.UK, 2017).

4.3. Conclusion

This chapter offers an overview of innovative policy approaches used on the one hand to promote digital technology adoption and diffusion, and on the other to stimulate more collaborative innovation. These are, as explored in previous chapters, two core objectives for innovation in the digital age.

Most experimental policy approaches to promote diffusion focus on facilitating the testing of new digital technology applications, involving the creation of test beds (to test new applications in controlled but near to real-world conditions) and regulatory sandboxes (to test new products or business models with reduced regulatory requirements). Innovative initiatives are also implemented to enhance early adoption of advanced digital technologies, by facilitating innovators' access to state-of-the-art facilities and expertise (e.g. in the field of AI and supercomputing). Traditional instruments to encourage technology adoption by SMEs – such as awareness-raising campaigns, innovation vouchers, technical assistance and training, and financial support – have been revisited to respond to specific challenges of the digital age, and often make use of opportunities offered by digital tools themselves.

Innovative instruments are also used to stimulate collaborative innovation. Most experimental approaches include the use of crowdsourcing and open challenges, as well as the creation of living labs, to find innovative solutions to pressing challenges and encourage co-creation. Intermediary organisations, such as Catapult Centres in the United Kingdom, have become central players in innovation ecosystems, and provide services such as matching firms needing technology solutions with potential suppliers. New research and innovation centres, often public-private partnerships, have also been created to provide spaces for multidisciplinary teams of public researchers and businesses to work together to address specific technology challenges. These often stand out for their innovative organisational structures. Examples include Data61 in Australia and Smart Industry Fieldlabs in the Netherlands. Traditional instruments such as cluster policies, the creation of networks, and provision of financial support continue to be implemented, but are used in new ways.

Annex 4.A1. Overview of country policy case studies

Annex Table 4.A1.1 presents an overview of the case studies contributed by countries to the OECD TIP Digital and Open Innovation project (2017-18). It provides a general description and an overview of some of their key insights. Full case studies will be made available on the publication's webpage.

Table 4.A1.1 Overview of country policy case studies

	General description	Items covered & insights from the studies
CSIRO – Data61 (Australia)	The case study presents the objectives, activities and mode of operation of Data61, the largest digital R&D centre in Australia. With more than 1 100 staff and an annual budget of USD 77 million. Data61 conducts fundamental and applied research, often in collaboration with other actors, benefiting from its digital and domain expertise.	- Describes Data61's organisational "<i>start-up culture</i>" adapted to digital innovation, including flatter organisational structures, and opportunities for researchers to experiment and take risks. A "challenge model" has been introduced whereby multidisciplinary teams are formed to address large-scale social & business challenges. - Explores Data61's <i>mixed funding model</i> that aims at having a balance between public and commercial sources of funding, to ensure that the organisation does not become a "work-for-hire" (consultancy-type) entity. The objective is to attract profitable, high-margin revenues to provide additional capacity to do self-directed fundamental and strategic research. - Insights on selected Data61 projects that contribute to <i>inclusive and sustainable growth</i> (e.g. development of software to simulate flood and mudflow scenarios in Chile, and recommend flood mitigation options; remote monitoring of biodiversity in the Amazon), as well as projects that promote <i>open data</i> in Australia (e.g. development of the NationalMap, a map-based visualisation and access tool for open government data).
Plattform Industrie 4.0 (Austria)	The case study analyses the role of the Plattform Industrie 4.0 in connecting key players in business, researchers, society and politics to shape the process of digital transformation so that it benefits all players. With an annual budget of approximately EUR 600 000, the Plattform has 8 active expert groups (with more than 200 experts involved), a co-ordinating office, a board of directors (which meets 4 times a year) and a general assembly (that meets once a year).	- Analyses key design dimensions for its <i>effective operation</i>, including the open character of the platform (e.g. non-exclusivity, strong network function), balanced representation of stakeholders (including policy, associations, NGOs, agencies, industry, research, experts), and mechanisms to enhance trust among stakeholders (i.e. clear responsibilities of each relevant actor, clear rules and processes for exchange, internal transparency on the different interests of different members). - Explains how the platform promotes the rollout of the <i>Industry 4.0 Readiness Check</i>, a maturity model developed jointly with other partners to evaluate the digitalisation readiness of firms. This independent and technology-neutral assessment, conducted by certified advisors, helps firms identify the steps necessary to become fully digitalised based on three dimensions: data (e.g. ability to capture, process and make meaningful use of large amounts of data); machine intelligence (e.g. the use of IoT solutions); and digital value creation (e.g. development of digital products). At the end of the assessment, specific recommendations are provided for firms to reach the target digital maturity level. - Insights on the Business Model Lab, which allows firms to <i>test new business model approaches</i> and <i>find partners</i>. To find partners, the initiating company prepares a short briefing to initiate a targeted search for partners. Once identified, the platform provides a proposal for dealing with intellectual property rights and acts as an advisor.
Digital Extension Centre (Chile)	The case study explores an initiative aimed at fostering adoption of digital technologies by SMEs in the agri-industry sector in the country's Maule region. With a public budget of CLP 300 million for 3 years (USD 742 000), the main areas of action of the Centre are education and training.	- Explains how the <i>structure and organisation of the centre</i> have been set up to ensure that the centre's activities are aligned with its general objectives, which respond to a vision shared among academia, business and the public sector. - Provides details of the specific <i>technology focus of the extension services provided</i>, which are in the fields of software and information systems; IoT and geolocation; networks and connectivity; storage and information management; and data analytics.

SME 4.0 Competence Centres (Germany)	The case study analyses how the network of <i>Mittelstand 4.0</i> Competence Centres in Germany is helping SMEs be aware of, test and adopt new digital solutions for their businesses. There are currently 23 competence centres, each with an annual budget of between EUR 1.5-2 million and a different structure and focus. Four agencies focus on specific issues of digitalisation (cloud, digital processes, communication and trade), and pass their expertise on to competence centres.	• Presents the range of support activities provided by the Competence Centres, highlighting the <i>uniqueness of each Centre</i>: each is led by a different consortium (composed of research institutions, universities and chambers of commerce). While offering cross-sectoral and cross-thematic support to SMEs, they differ in the focus of their activities (e.g. digital product development, networked value chains, new production technologies, new business models, labour 4.0, IT security, digital marketing). There are also 6 competence centres that focus on specific sectors (e.g. textile, crafts, smart building). • Explains the use of <i>demonstration factories</i> to support SMEs test Industry 4.0 solutions. In these plants, mostly run by universities or scientific institutions, simulation of business and production processes allows entrepreneurs to explore how digital technologies would change their businesses. The digital focus of these plants varies across competence centres (e.g. 3D printing, sensors, production control software, etc.)
Research-Create-Innovate programme (Greece)	The case study explores a policy initiative aimed at fostering research in digital-related technologies that are of relevance to key economic areas in Greece. With a total budget of EUR 410 million (EUR 77 million on the ICT domain), the initiative provides grants to SMEs, firms and research centres that conduct research and innovation in key priority domains.	• Explores the <i>innovative policy design approach</i> to identify key priority areas for programme support. This approach involves several steps: 1) identifying key economic domains based on an initial assessment of statistical data and studies; 2) identifying main economic activities within each domain through a broad consultation with other ministries, regions, research centres and industry associations; 3) identifying main value-added activities and supporting technologies, through broad consultation with the business community and an innovation platform that allows participants to exchange views and information on industry priorities; 4) conducting a SWOT analysis for identified technologies; and 5) organising a final open consultation to maximise inputs and raise awareness about the initiative. • Digital technologies play a key role in most selected priority areas for support. The case study presents a detailed list of all <i>ICT-related priorities</i>, including activities where ICT is the main domain and those where ICT works as a key enabler (e.g. in the fields of agri-food, creative industries, materials and construction, sustainable development, health, transport, logistics).
Smart Industry Fieldlabs (Netherlands)	This case study explores how 10 specific Smart Industry FieldLabs support and accelerate the development, testing and implementation of smart industry solutions. With a total investment of EUR 72 million between 2015 and 2018, these public-private partnerships cover at least 2 ICT technologies each and together address the needs of more than 15 sectors.	• The technology developments of the 10 <i>fieldlabs contribute to the 8 ongoing smart industry transformations</i> identified by the Dutch Smart Industry roadmap 2018 (i.e. smart products, servitisation, digital factories, connected factories, sustainable factories, smart working, advanced manufacturing and flexible manufacturing). The case study finds that fieldlabs mainly focus on ICT innovations with a high level of technology readiness. • <i>Each fieldlab is unique</i>: they have a focus on specific sectors or application fields, are initiated by different types of actors (e.g. public sector, firms, knowledge institutes), and engage to different degrees in international collaboration. Nonetheless, they also have important commonalities: they have on average 20 partners, have a non-hierarchical structure, use a project-based approach, and in most cases have a physical test location to carry out their activities.
Digital Catapult Centre (United Kingdom)	The case study explores the role of the Digital Catapult Centre in connecting businesses with the research and academic communities, and in helping them commercialise innovations. With an annual budget of around GBP 20 million, it focuses on 2 market segments (digital manufacturing and creative industries) and 3 key technologies (artificial intelligence and machine learning; future networks including 5G; and immersive technologies, e.g. augmented reality).	• Insights on a range of <i>innovative support activities</i>, e.g. Pit Stop events to encourage open innovation between large and small firms and academia; Augmentor, a 10-week equity-free programme supporting early-stage businesses working with immersive technologies • The Centre is <i>organised functionally</i>, ensuring clear ownership and responsibility for activities and outputs. To drive delivery of programmes, it establishes <i>multi-functional teams</i> of technologists, business specialists, product and product managers, and policy, research and innovation experts – all supported by centralised finance, sales and bidding, IT, human resources, and marketing and events functions. • In-depth analysis of 3 specific projects: 1) <i>Things Connected</i>, which facilitates access of UK enterprises to advanced technology test beds, to experiment and prototype new IoT products and services; 2) the <i>Dimension Studio</i>, aimed at facilitating firms' access to leading-edge immersive production and demonstration facilities, with the objective to boost immersive content creation in the United Kingdom; and 3) the <i>Machine Intelligence Garage</i>, which helps businesses access the computation power and expertise they need to develop and build machine learning and artificial intelligence solutions.

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Digital Innovation

SEIZING POLICY OPPORTUNITIES

This report discusses how the digital transformation – digital technologies, data and software, AI-based analytics and other advances – is changing innovation processes and outcomes. It highlights the general trends across the economy and factors behind sector-specific dynamics, including increasing use of data as a key input for innovation, the expanding possibilities for experimentation offered by virtual simulation, 3D printing and other digital technologies, and the growing focus on services innovation enabled by digital technologies.

In view of such changes, this report evaluates how innovation policies should adapt to foster innovation and inclusive development in the digital age, and identifies priority areas for policy action. It also explores novel innovation policy approaches implemented by countries to foster digital technology adoption and collaborative innovation.

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