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Advanced Technologies for Industry – Methodological report

Indicator framework and data calculations

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Section 1

1. Introduction

The purpose of this document is to present the scope of measurement and methodology underpinning the indicator framework and data calculations of the **'Advanced Technologies for Industry'** (ATI) project. The ATI has been initiated by the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the European Innovation Council and Small and Medium-sized Enterprises Executive Agency. The project and the methodological framework aligns two previous European Commission initiatives notably the Key Enabling Technologies (KETs) Observatory and the Digital Transformation Monitor (DTM).

The conceptual design of the project follows the role of advanced technologies in industrial modernisation and aims at providing policymakers, industry representatives, researchers and other relevant stakeholders with a set of monitoring tools that can be used to capture opportunities of industrial transformation facilitated by technological advancements.

The starting point of this analysis has been 16 advanced technologies that are a priority for European industrial policy, which enable process, product and service innovation throughout the economy and hence foster industrial modernisation. The advanced technologies within the focus of this report include Advanced Materials, Advanced Manufacturing, Artificial Intelligence, augmented and virtual reality, Big Data, Blockchain, cloud technologies, connectivity, Industrial Biotechnology, Internet of Things, Micro- and Nanoelectronics, Mobility, Nanotechnology, Photonics, Robotics, and IT for Security/Cybersecurity.

This methodological report has nine main chapters, each addressing a specific aspect of the data calculations and implementation of the data collection:

- Chapter 2 outlines the conceptual framework
- Chapter 3 includes the list of definitions of advanced technologies
- Chapter 4 presents the indicator framework
- Chapter 5 highlights the methodology and codes used to capture advanced technologies through patents, trade and PRODCOM
- Chapter 6 describes the survey
- Chapter 7 provides the methodology applied in the text-mining of company websites
- Chapter 8 details the LinkedIn data calculations
- Chapter 9 presents the process of linking Crunchbase and Dealroom in order to reflect about investment trends
- Chapter 10 summarises the calculation methods of the composite scores.

Section 2

2. Conceptual framework for monitoring Advanced Technologies for Industry

The rapid rise of advanced technologies is transforming businesses, industries and the society and it is profoundly changing the future competitiveness and employment dynamics of countries. Understanding the trends in the level of technology production and the uptake of various technologies and their impact across sectors and countries can help policymakers and businesses alike taking more appropriate decisions. Main policy questions are related to the maturity level and adoption rate of advanced technologies, the trends in key enabling factors such as skills, investment or entrepreneurship and comparison of the EU27 performance to key competing economies.

In constructing a conceptual framework of a monitor of 'Advanced Technologies for Industry', a comprehensive literature review has been performed. Inspiration was taken among others from two recent, complementary studies conducted in this area, notably the results of the 'Towards better monitoring innovation strengths, regional specialisation and business environment[1]' project (TBM) and the methodological basis developed in the framework of the ESPON 'Technological transformation of regions' project (Radosevic, 2019).

Following these studies, a similar definition for industrial modernisation is adopted for the purposes of this project, but it is put into the specific context of advanced technologies, notably it is defined as the *transformation and upgrading processes that aim at maintaining or increasing the competitiveness of European manufacturing and services industries through the generation and use of advanced technologies.* Industrial modernisation is seen as a process that integrates available technologies and new business models and hence radically changing the nature of production and business operations relevant both to manufacturing and services and thus having a far-reaching organisational and economic implications (Radosevic, 2019). Industrial modernisation goes beyond the generation of new products and technologies and describes a change in firms' mode of operation (Van de Velde et al, 2019). In this perspective, the aim of European, national and regional policies is to enable a successful industrial transformation towards a digital, knowledge-based, decarbonised and more circular industry in Europe (European Parliament, 2018).

In the context of industrial modernisation, advanced technologies are defined as recent or future technologies that are expected to substantially alter the business and social environment and include Advanced Materials, Advanced Manufacturing, Artificial Intelligence, augmented and virtual reality, Big Data, Blockchain, cloud technologies, connectivity, Industrial Biotechnology, Internet of Things, Micro- and Nanoelectronics, Mobility, Nanotechnology, Photonics, Robotics, and Cybersecurity as also listed in the Introduction. They also include new and promising technologies such as edge computing, digital fight to fake news, personal data digital twins, neuromorphic computing, quantum computing, evolution of lithium-ion technology, smart dust, affective computing, ingestible technologies, smart food, biometrics, brain computer interfaces and others.

Industrial modernisation through advanced technologies is embedded in the societal-economic change called the '4th industrial revolution' driven by technological opportunities and digital transformation. As Schwab (2017) writes "digital technologies that have computer hardware, software and networks at their core are not new, but they are becoming more sophisticated and integrated and as a result are transforming societies and the global economy". In this respect, the new nature of the 4th industrial revolution is not only in digitalisation but in fusion with new and not yet deployed technologies. The final report of the study on 'Towards better monitoring innovation strengths, regional specialisation and business environment' differentiates the following factors that affect the ability for industrial modernisation:

- Innovation capacity to develop new and improve existing products and processes, including the generation of new knowledge (e.g. R&D), the adoption and usage of advanced technologies, in particular digital and key enabling technologies, and investment in new equipment, infrastructures and intangible assets;
- Managerial and organisational capabilities to master new challenges, including the disruptive transformation of industries (e.g. through the emergence of digital-based platforms), servitisation,

[1] https://op.europa.eu/en/publication-detail/-/publication/8e2d2352-d5cf-11e9-883a-01aa75ed71a1

changes in markets and customer demands, such capabilities include reactiveness and anticipation, flexibility, and fast decision-making;

- Skills development in order to prepare the workforce for new requirements and new models of production and collaboration, ranging from education to vocational training and on-the-job learning and including human resource management practices such as improving workplace environments;
- Openness and the capacity to cooperate, build and develop clusters and networks along value chains, and to engage in joint activities with academia and the wider research and innovation community both on a regional and global scale;
- Industrial sustainability, including energy saving, resource-efficient and environmental friendly production processes and eco-innovative solutions.

2.1 Technology value chain

Technology generation

Technological transformation divides the socio-economic fabric into technology generators and technology users. The producers of advanced technologies are to be found for instance in universities, research centres and technology companies. The production of new technology can be captured by the number of patents in a comprehensive and comparable manner for all EU countries. Patent data are a widely used measure for tracking technology development activities (KETs Observatory, 2013). Patents refer to technical inventions that contain new knowledge, have a potential for commercial application and have proved a certain level of technical feasibility. Patents are regarded as a first step in the deployment of new technological knowledge. Patenting activity, however, differs among technologies since not all new technologies or the full range of technologies are patented. It is also important to take into account that not all EU countries have the same level of patenting activity.

Technology uptake

Advanced technologies can be taken up by industries, businesses or the public sector such as healthcare or transport. Technology uptake is evident in startup and spin-off firms that were born with the idea to commercialise a specific technology and revolutionise traditional way of business. For instance, some food tech platforms help creating restaurants equipped with autonomous robots cooking and serving clients. Some traditional companies are also more open to technological change and they embed early on technology in their production and business processes or materialise a new product or services based on digital media or platforms.

Technology uptake is embedded in the vast academic literature on technology diffusion (Geroski, 2000) that deals with the success, rate and failure of new technologies in moving across a market. Diffusion of technologies is seen primarily as the outcome of a learning or a commercial process and resistance to adopt an innovation as a function of the individual's propensity. New technologies are also seen as an opportunity to increase productivity and to impact economic growth, employment or the environment. There are various possible adoption scenarios and as Rosenberg (1983) stated: “One of the most important unresolved issues is the rate at which new and improved technologies are adopted”. Diffusion rate have been so far often studied through methodologies such as historical analogies, expert interviews, panel consensus, trend projections and scenario development. Some authors argued that if the technological distance between goods is sufficiently large, the economy is trapped in a no-growth equilibrium where innovations remain isolated events, while if it is sufficiently short, innovations eventually percolate throughout the whole economy, leading to the emergence of general purpose technologies and sustained long run growth (Andergassen et al, 2017). Another important dimension in the literature on diffusion is the pace of spreading existing technologies from national frontier firms to laggard firms.

Certain new technologies are more relevant for specific industries. Different sectors have distinct propensities to integrate digital or other technologies into their business operation and products. Industrial Internet of Things has been applied in equipment manufacturing, logistics, automotive, agriculture or construction. Robotics has influenced manufacturing industries starting from automotive industry to semiconductor and electronics or plastics. Most recently Robotics is also taken up by food manufacturers. Industrial Biotechnology helps creating bio-based products in sectors such as chemicals, food and feed, detergents, paper and pulp, textiles and bioenergy. Companies, however, encounter obstacles to using advanced technologies at a transformative scale due to the number and breadth of technology solutions required to truly transform an enterprise and redesigning a company’s processes to capture the value of new technologies[2] (McKinsey, 2018).

[2] https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/the-cornerstones-of-large-scale-technology-transformation

Technology diffusion is hard to capture especially when we talk about sub-areas of technologies such as deep learning within Artificial Intelligence. A recent OECD (2018) study offers a sectoral taxonomy of digital intensity and shows big differences between traditional sectors (agriculture, mining, food) being currently much less digitally intensive and technology-intensive sectors like machinery and equipment, transport equipment or services like R&D and finance. However, it also shows that some traditional sectors like textiles, wearing apparel are more digitally intensive than transportation or accommodation and food services. Differences in the ability to capture value from new technologies also exist between advanced and less advanced firms within the same sectors, which is not surprising.

2.2 Enabling conditions

Technology development and uptake thrive best in national, regional and city environments that provide the right conditions to nurture entrepreneurs, businesses and citizens who drive and make the best use of technological advancements for the modernisation of industry and for the benefit of society. The first pillar of enabling conditions is the type of inputs that are available for the innovation and transformation process. The key enabling factor includes first of all human skills that support both the technology generation and diffusion process. Crucial inputs such as business investments and innovation form important building blocks towards a stronger technology-based industry. The business environment that is most importantly determined by the quality of infrastructure, available support services, the creativity of entrepreneurs and the quality of cooperation linkages constitutes another key pillar of enabling conditions.

Skills

Economic activity is fueled by the acquired and useful abilities of all the inhabitants or members of the society as already defined by Adam Smith. In macro-economic growth theory, there is broad agreement on the human capital as a key ingredient in explaining economic growth. By human capital the OECD refers to the importance of people – their abilities, their knowledge and their competences. From a company's perspective, an increasing share of its value comes from intangible rather than tangible assets including for instance knowledge. The importance of intangibles is further driven by the transformation of industry with technology acting as an enabler and skills a key asset in a company's successful transformation. Monitoring the supply and demand of skills is thus of high relevance to policymakers. The latest EU action is the New Skills Agenda for Europe, which was adopted by the European Commission in 2016. Part of this initiative are the actions on skills intelligence and in particular the Blueprint for Sectoral Cooperation on Skills.

Investments

Innovation and investments refer to the introduction and diffusion of production processes and business models that are at least new to the firm and they also reflect targeted inputs to industrial modernisation. Investment refers to the addition of capital goods (i.e. assets) by firms (capital expenditure). More broadly speaking, it is more and more considered that 'any use of resources that reduces current consumption in order to increase it in the future should qualify as an investment' (EC, 2016). As described in the 'Towards better monitoring' study, business investment can include both investment in tangible assets (machinery, equipment, buildings) and intangible assets (software and database, other intellectual property, firm-specific human capital, firm-specific organisational capital, firm-specific marketing capital: branding, reputation).

Innovation capacity

Innovation is widely accepted as a crucial element in driving economic development and is fostered by technological change. Innovation capacity of nations refers to the ability of a country to produce and exploit new products, services, systems or processes over long periods of time. In this study, it is understood as the innovativeness of firms, including the adoption and usage of advanced technologies, in particular digital and key enabling technologies, and investment in new equipment, infrastructures and intangible assets and it is mainly captured by indicators of the Community Innovation Survey.

Infrastructure

Infrastructure constitutes one of the basic national and regional endowments that determines the operational environment for firms and their industries. Infrastructure represents both the physical infrastructure and the digital infrastructure that are the framework conditions for industrial modernisation and technological change.

Entrepreneurship

Entrepreneurship is a key ingredient for industrial change, adaptation and self-organisation (Feldman, 2005). Entrepreneurship can be defined as "the capacity and willingness to develop, organise and manage a business venture along with any of its risks in order to make a profit". It is often understood as the mix of entrepreneurial attitudes, entrepreneurial activity and entrepreneurial aspirations (Acs et al, 2008). By measuring the level of entrepreneurship, the existing business dynamics can be understood as fostering the process of new business creation or the further development of existing ventures. Cross-sectoral dynamics should be also highlighted that play a special role in entrepreneurship. Dynamics in one sector can have a positive or negative effect on the dynamics of other sectors. Intended or unintended cross-sectoral encounters can create new opportunities for so far non-existent ventures, new technological combinations or new business models. Nevertheless, they can also shake the industrial value chain and weaken the conditions for other related industries (Rivera and Izsak, 2016).

Collaboration

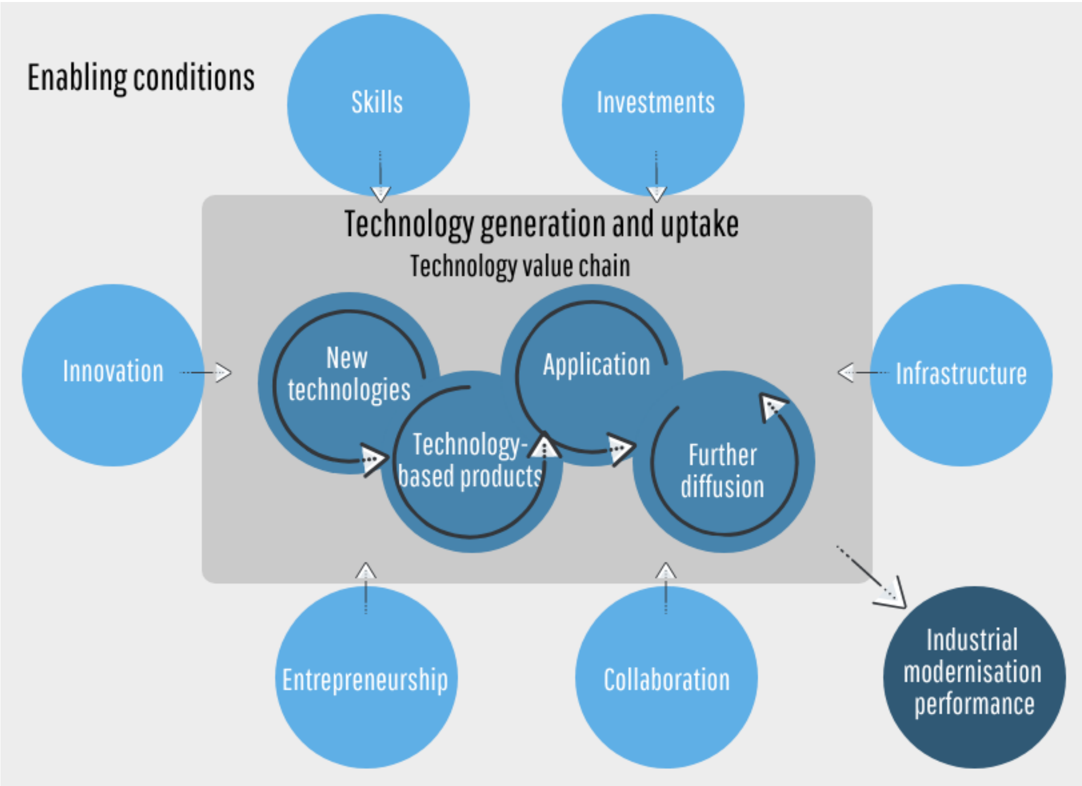
Collaboration and cooperation reflect the level of connections among firms and between universities, businesses and the public sector. Business competitiveness depends not only on innovation and investments per se but on the ability to enter into new forms of collaboration with suppliers and clients, and combine products with services (Rammer, 2019). Industrial activities are integrated in complex value chains and the relationships among the industrial actors and especially among firms is an important determinant of industrial modernisation. Another relevant aspect of collaboration linkages is the dynamism happening between different sectors. These cross-sectoral linkages can enable the region to build novel industrial profiles (Trippl et al, 2014).

Industrial modernisation performance

Policymakers and business representatives are both in need to understand the actual outcomes and impact of industrial modernisation reflected through better competitiveness, more growth and jobs as well as more sustainability. Technological change, demand and employment are connected through productivity growth that originates from different effects such as lowering prices to higher demand; growing real wages to higher demand, and labour displacement to higher unemployment and lower demand (Dosi and Virgillito, 2019). Technological change has especially a profound impact on employment. According to Autor (2015), digital technologies turn out to be substitutes for the more routinised activities and complement for high-skilled non-routinised jobs, with more limited effects on low-skilled, non-routinised jobs. An important question in the academic literature is the productivity growth that is gained from technological advancements; however, it is not yet very well understood how the productivity growth performance of global frontier firms evolves over time in both absolute terms and relative to laggard firms (OECD, 2015).

Following the above presented building blocks of advanced technologies for industry, we depict the conceptual framework in Figure 1.

Figure 1: Conceptual building blocks to monitor advanced technologies for industry



Source: Technopolis Group – further developed following TBM, KETs Observatory and DTM

Section 3

3. Definition of technologies

The advanced technologies covered in the 'Advanced Technologies for Industry' project include the following:

Advanced Manufacturing Technology

Advanced Manufacturing technology encompasses the use of innovative technology to improve products or processes that drive innovation in manufacturing. It covers two types of technologies: process technology that is used to produce any of other advanced technologies, and process technology that is based on Robotics, automation technology or computer-integrated manufacturing. For the former, such process technology typically relates to production apparatus, equipment and procedures for the manufacture of specific materials and components. For the latter, process technology includes measuring, control and testing devices for machines, machine tools and various areas of automated or IT-based manufacturing technology.

Advanced Materials

Advanced Materials lead both to new reduced cost substitutes to existing materials and to new higher added-value products and services. Advanced Materials offer major improvements in a wide variety of different fields, e.g. in aerospace, transport, building and health care. They facilitate recycling, lowering the carbon footprint and energy demand as well as limiting the need for raw materials that are scarce in Europe.

Artificial Intelligence

Artificial Intelligence is a term used to describe machines performing human-like cognitive functions (e.g. learning, understanding, reasoning or interacting). It comprises different forms of cognition and meaning understanding (e.g. speech recognition, natural language processing) and human interaction (e.g. signal sensing, smart control, simulators). Artificial Intelligence is a heterogenous field in terms of its technology base. While some aspects like sensors, chips, robots as well as certain applications like autonomous driving, logistics or medical instruments refer to hardware components, a relevant part of AI is rooted in algorithms and software.

Augmented/Virtual Reality

Augmented reality devices look to overlay digital information or objects with a person's current view of reality. As such, the user is able to see his/her surroundings while also seeing the Augmented Reality content. Virtual reality devices place end users into a completely new reality, obscuring the view of their existing reality.

Big Data

Big Data is a term describing the continuous increase in data, and the technologies needed to collect, store, manage and analyse them. It is a complex and multidimensional phenomenon, impacting people, processes and technology. From a technology point of view, Big Data encompasses hardware and software that integrate, organise, manage, analyse and present data. It is characterised by "four Vs": volume, velocity, variety and value. Big Data technologies are new generation of technologies and architectures, designed to economically extract value from very large volumes of a wide variety of data, by enabling high-velocity capture, discovery and/or analysis.

Blockchain

Blockchain is a digital, distributed ledger of transactions or records, in which the ledger stores the information or data and exists across multiple participants in a peer-to-peer network. Distributed ledgers technology allows new transactions to be added to an existing chain of transactions using a secure, digital or cryptographic signature. Blockchain protocols aggregate, validate, and relay transactions within the Blockchain network. Blockchain technology allows the data to exist on a network of instances or 'nodes', allowing for copies of the ledger to exist rather than being managed in one centralised instance.

Connectivity

Connectivity refers to all those technologies and services that allow end-users to connect to a communication network. It encompasses an increasing volume of data, wireless and wired protocols and standards, and combinations within a single use case or location.

Standard connectivity includes Fixed Voice and Mobile Voice telecom services to allow fixed or mobile voice communications, but also Fixed Data and Mobile Data services to have access and transfer data via a network.

Advanced connectivity that is in the focus of the ATI project refers to the rise of Internet of Things scenarios, where connectivity technology boundaries expand beyond wired and cellular (e.g. 4G, 5G) services to Low Power Wide Area Network (LPWAN), Satellite and Short Range Wireless technologies.

Cloud computing

Cloud computing includes the delivery of tools and applications like data storage, servers, databases and software based on a network of remote servers through the Internet. Cloud computing services enable users to store files and applications in a virtual place or the cloud and access all the data via the Internet.

Public Cloud services that have been explored specifically by the ATI survey are available on public networks and open to a largely unrestricted universe of potential users. Public clouds are designed for a market, not a single enterprise.

Industrial Biotechnology

Industrial Biotechnology is the application of biotechnology for the industrial processing and production of chemicals, materials and fuels. It includes the practice of using microorganisms or components of micro-organisms like enzymes to generate industrially useful products in a more efficient way (e.g. less energy use or less by-products), or generate substances and chemical building blocks with specific capabilities that conventional petrochemical processes cannot provide. There are many examples of such bio-based products already on the market. The most mature applications are related to enzymes used in the food, feed and detergents sectors. More recent applications include the production of biochemicals and biopolymers from agricultural or forest wastes.

Internet of Things (IoT)

The Internet of Things (IoT) refers to the network of smart, interconnected devices and services that are capable of sensing or even listening to requests. IoT is an aggregation of endpoints that are uniquely identifiable and that communicate bi-directionally over a network using some form of automated connectivity. Objects become interconnected, make themselves recognisable and acquire intelligence in the sense that they can communicate information about themselves and access information that has been provided by another source. The Internet of Things relies on networked sensors to remotely connect, track and manage products, systems and grids. The Industrial Internet of Things (IIoT) – a subset of the larger Internet of Things – focuses on the specialised requirements of industrial applications, such as manufacturing, oil and gas, and utilities. IIoT systems connect non-consumer devices, used by companies, governments and utility providers in their service delivery.

Micro- and Nanoelectronics

Micro- and Nanoelectronics deal with semiconductor components and highly miniaturised electronic subsystems and their integration in larger products and systems. They include the fabrication, the design, the packaging and testing from nano-scale transistors to micro-scale systems integrating multiple functions on a chip.

Mobility

IT for Mobility

Mobility covers a large number of different technology areas and markets, which does not only encompass vehicles that take people from point A to point B, but also includes all kinds of technologies that make people more mobile (like for example mobile phones). These, however, consist of a large set of sub-technologies that are hard to capture at the same time. In this project, the patent, trade, PRODCOM, investment and skills analysis focus on a sub-section of Mobility, which is related to vehicles only, e.g. satellite navigation and radio-location, which are also the core technologies that are necessary to make autonomous driving work.

Enterprise Mobility

The ATI business survey has captured Mobility in terms of the workforce. The enterprise Mobility market is made up of a conglomeration of mobile solutions and technologies, including hardware, software and services, empowering a borderless workforce to securely work anywhere, at any time and from any device. It does not include only the provision of smartphones or tablets to the workforce but also all the tools and applications for transforming key processes, from internal operations to operations with customers and suppliers, all the way from the shop floor to the top floor and from the back office to the end customers.

Nanotechnology

Nanotechnology is an umbrella term that covers the design, characterisation, production and application of structures, devices and systems by controlling shape and size at nanometer scale. Nanotechnology holds the promise of leading to the development of smart nano and micro devices and systems and to radical breakthroughs in vital fields such as healthcare, energy, environment and manufacturing.

Photonics

Photonics is a multidisciplinary domain dealing with light, encompassing its generation, detection and management. Among other things it provides the technological basis for the economic conversion of sunlight to electricity which is important for the production of renewable energy, and a variety of electronic components and equipment such as photodiodes, LEDs and lasers.

Robotics

Robotics is a technology that encompasses the design, building, implementation and operation of robots. Robotics is often organised into three categories: 1) Application specific. This includes Robotics designed to conduct a specific task or series of tasks for commercial purposes. These robots may be stationary or mobile but are limited in function as defined by the intended application. 2) Multipurpose. Multipurpose robots are capable of performing a variety of functions and movements determined by a user that programs the robot for tasks, movement, range and other functions and that may change the effector based on the required task. These robots function autonomously within the parameters of their programming to conduct tasks for commercial applications and may be fixed, 'moveable' or mobile. 3) Cognitive. Cognitive robots are capable of decision making and reason, which allows them to function within a complex environment. These robots can learn and make decisions to support optimal function and performance and are designed for commercial applications. When measuring production and uptake of Robotics, industrial applications will be taken into account.

IT for Security/ Cybersecurity

Cybersecurity products are tools designed using a wide variety of technologies to enhance the security of an organisation's networking infrastructure — including computers, information systems, internet communications, networks, transactions, personal devices, mainframe and the cloud — as well as help provide advanced value-added services and capabilities. Cybersecurity products are utilised to provide confidentiality, integrity, privacy and assurance. Through the use of security applications, organisations are able to provide security management, access control, authentication, malware protection, encryption, data loss prevention (DLP), intrusion detection and prevention (IDP), vulnerability assessment (VA) and perimeter defense, among other capabilities.

The definitions of Advanced Materials, Advanced Manufacturing technologies, Industrial Biotechnology, Nanotechnology, Micro- and Nanoelectronics and Photonics in this project follow the previous KETs Observatory approach which was to develop a set of technologies that have an enabling character for other areas and sectors. At the same time, these technologies should be sufficiently mature so that (statistical) effects on all parts of the value chain and all indicators - patents, employment, production, trade - can be expected. The definitions of these technologies are generally broad in nature and focus on the impact on industry and society.

The digital technologies included in this project follow the Digital Transformation Monitor's conceptual framework (Artificial Intelligence, Augmented and Virtual Reality, Big Data, Cloud technologies, Cybersecurity, Connectivity and Robotics). We do not take into account social media anymore given that this technology has become mainstream. The additional technologies and the relabeling suggested has been made bearing in mind the industry as user of the project's outputs and more specifically the technology use survey of companies and thus the need to clearly communicate to industry about the technology addressed.

High Level Expert Group recommendations

To define advanced technologies, the recommendations of the High-Level Expert Group have been consulted. The final definitions listed above were chosen taking into account the objectives of this project, namely the creation of a data driven monitoring framework, and the context of industrial modernisation. Some deviations from the recommendations where thus considered necessary.

In particular, the proposition of taking 'Life Sciences technologies' (instead of 'Industrial Biotechnology') was considered to be too broad and was therefore not included. Life Sciences is a field that is much broader than all others. It would encompass several entire sectors or a very broad technological area (to some extent even a whole 'Societal Grand Challenge'), which does not leave any room for the original idea of KETs, namely the enabling character.

The High-Level Expert Group has also recommended to merge 'Advanced Materials' with 'Nanotechnology' and 'Photonics' with 'micro/nano-electronics'. While merging several fields is possible, the ATI methodological framework kept the existing definitions, as this allowed the analysis of a longer time period and more disaggregated data to better monitor the development of the single technologies.

On the other hand, Blockchain as a recommended additional technology is too narrow and not yet covering the full value chain, hence it could not be captured through patent analysis.

Concerning the fields of 'Artificial Intelligence' and 'IT for Security', both have been included in the data collection but the result captures a narrower field as the 'purely' software-based components of these technologies are hard to cover.

Section 4

4. Indicator framework and data repository

4.1 Alignment of the KETs Observatory and Digital Transformation Monitor indicator framework

In this section we present the indicators that aim to capture each pillar of the ATI conceptual framework. The list is the result of an assessment of the KETs Observatory, the Digital Transformation Monitor and a further selection of novel indicators based on exploratory data sources. In addition, the project also implements the final result of the 'Towards better monitoring innovation strengths, regional specialisation, and business trends in support of industrial modernisation in the EU' project including a shortlist of 30 indicators.

Indicators have been collected for the EU27 and EU28 and where possible also for extra-European countries notably the USA, China, Japan, Korea, Canada and Russia.

Time coverage of the indicators starts from 2005 in the case of the patent analysis and it includes historical data when it is available.

The list of indicators takes into account the following criteria:

1. The conceptual suitability of technology generation indicators by technology
2. The outcome of the user survey
3. S.M.A.R.T. criteria for the selection of indicators (specific, measurable, achievable and attributable, relevant and timely)

The original list of KETs Observatory and Digital Transformation Monitor indicators have been reviewed and rationalised keeping in mind the user requirements as identified during the comprehensive user needs assessment exercise conducted prior to this methodological report. Some of the indicators that had been less appreciated by the users have been dropped and research questions that are on the priority list of the users have been addressed by new indicators and data sources.

The two original monitors are aligned with regard to three important aspects:

1. The original 6 KETs and 7 digital technologies have been revised as presented in the previous Chapter and in line with this the indicator framework will **cover a consolidated list of advanced technologies** from now on.
2. The value chain based methodological approach of the KETs Observatory and the focus of the Digital Transformation Monitor on enabling conditions and technology uptake have been merged in a **new conceptual framework** as presented in Chapter 2 and this new concept **forms the basis of the main dimensions** of the renewed set of indicators.
3. Indicators for technology generation and uptake are calculated in the case of the technologies where it makes sense. For instance, patent-based indicators are not calculated for Blockchain given that this technology is usually not based on patents. Enterprise Mobility has been calculated through the survey only.

The alignment between the KETs Observatory and DTM for technology-specific indicators is summarised in Table 1. It includes the indicators that have been included considering their relevance for the technologies in focus. In addition, limitations in production and trade data also apply and are equally reflected. The main factor under consideration is that digital technologies represent software ideas rather than hardware, which generally do not have patents and tend to be protected as industrial secrets. In addition, patents on pure software are not patentable at the European Patent Office (EPO) as well as many national patent offices in Europe.

Table 1: List of indicators and data sets related to the aligned set of advanced technologies

Advanced Technologies	**KETs Observatory main indicators**			**DTM main indicators**	
	Patents	**Production**	**Trade**	**Consumption**	**Adoption**
Advanced Manufacturing Technology	#%	%	%		%
Augmented Reality/ Virtual Reality				€	%
Big Data	#%	%	%	€	%
Blockchain				€	%
Cloud computing				€	%
Artificial Intelligence	#%	%	%	€	%
IoT	#%	%	%	€	%
IT for Mobility	#%	%	%	€	%
Enterprise Mobility				€	%
Robotics	#%	%	%	€	%
IT for Security	#%	%	%		%
Standard and Advanced Connectivity					%
Advanced Materials	#%	%	%		%
Industrial Biotechnology	#%	%	%		%
Micro & Nanoelectronics	#%	%	%		%
Nanotechnology	#%	%	%		%
Photonics	#%	%	%		%
Data Source	PATSAT	PRODCOM	COMTRADE	IDC Spending Guide	Survey

€ = revenue/cost value	# = numeric value	% = share, penetration value

Source : authors

4.2 List of indicators and data sources

4.2.1 Value chain indicators: Technology generation and exploitation

Technology generation and exploitation have been captured through patenting activity and production and trade of technology-based components in the EU countries. The patent indicators measure the ability to produce new technological knowledge relevant to industrial application. Production indicators measure the relevance and dynamics of the production and absorption of advanced technology based components. Trade indicators measure the trade activities related to advanced technology based components. Technology generation and exploitation are analysed at national level.

The country coverage of the indicators is the following:

In the case of the patent analysis:

- In total, 45 different countries are considered: EU27, UK as well as Brazil, Canada, China (incl. Hong Kong), Iceland, India, Israel, Japan, Mexico, Norway, Russia, Singapore, South Africa, South Korea, Switzerland, Taiwan, Turkey, and the US. With respect to the regional split, Europe includes also the following countries in addition to EU28: Albania, Andorra, Bosnia-Hercegovina, Iceland, Lichtenstein, North Macedonia, Monaco, Montenegro, Norway, San Marino, Serbia, Switzerland. East Asia region includes Japan, China (incl. Hong Kong), Korea, Singapore, Taiwan. Finally, North America region includes US, Mexico, Canada.

In production indicators:

- EU24, UK (Cyprus, Malta and Luxembourg are exempt from reporting PRODCOM data)

In trade:

- 44 countries (Taiwan is missing in trade analysis, because the country is not covered by international trade databases)
- With respect to the regional split, Europe includes EU27 Member States, UK, East Asia includes China, Japan, India, Singapore, Republic of Korea and North America includes US, Canada and Mexico.

Crunchbase and Dealroom:

- EU27, UK, US, China, Russia, Canada, Korea, Japan

LinkedIn:

- EU27, UK, US

The definitions of the Internet of Things, IT for Mobility, Robotics, IT for Security, Connectivity and – in particular – Artificial Intelligence and Big Data include terminology to capture relevant embedded software technologies to the extent realistic and feasible (through patent classes and dedicated keywords). In doing so, the study team relied on pre-existing and tested practices by major patent offices (e.g. EPO) and/or international organisations (e.g. OECD).

The dimension of software and algorithms in Artificial Intelligence is hardly identifiable in patent data. Also in other classifications it is impossible to identify it directly, as AI is 'hidden' in software categories in general. For example, the software industry as such might be identifiable, but the share of AI next to operating systems or PC applications/software can hardly be identified. This holds for NACE (employment, production), but also for PRODCOM (trade). The PRODCOM and trade analysis mainly captures the hardware part. The software components of AI are covered by the applications and the so-called embedded software as well as computer-implemented inventions (software patents). The (more or less solely) software-based component of AI is hard to tackle.

It is possible to file patents for Cybersecurity applications and for the processes and based on this in conjunction with our empirical approach, the relevant sectors (NACE) or products (PRODCOM) have been identified.

In the following tables we provide an overview of the indicators included in the ATI project. Detailed metadata (including geographical coverage and time period) about each indicator are available on the ATI dashboard (available here: https://ati.ec.europa.eu/data-dashboard/country).

Table 2: Technology generation and exploitation indicators

Conceptual pillar	Source	Indicator	Description
New technologies	Patstat	*Advanced Technologies (AT) country share in global patenting ('share')*	Share of patent applications in each of the ATs/ all ATs combined in all global applications in the respective AT, value is calculated also for all ATs combined (patapp $technology_{country}$/patapp $technology_{world}$)
New technologies	Patstat	*Advanced Technologies country specialisation in patenting ('specialisation')*	Share of each of the ATs/all ATs combined in a country's patenting compared to their share in global patenting (transformed on a scale between -100/+100)
New technologies	Patstat	*Advanced Technologies (AT) share in countries' patenting ('significance')*	Share of patent applications in each of the ATs/ all ATs combined in the respective country's total number of patent applications (patapp $technology_{country}$/patapp $total_{country}$)
New technologies	Crunchbase and Dealroom merged dataset	*Number of AT firms*	Number of firms producing specific advanced technologies calculated based on categories and search in company descriptions
Technology-based products	PRODCOM	*Advanced Technologies (AT) country share in global production ('share')*	Share of a country's production in each of the ATs/ all ATs combined in all global production in the respective AT/ value is calculated also for all ATs combined (prod $technology_{country}$/prod $technology_{world}$)
Technology-based products	PRODCOM	*Advanced Technologies country specialisation in production ('specialisation')*	Share of each of the ATs/all ATs combined in a country's production compared to their share in global production
Technology-based products	PRODCOM	*Advanced Technologies (AT) share in countries'*	Share of a country's production in each of the ATs/ all ATs combined in the respective country's total production

		production ('significance')	(prod $technology_{country}$/prod $total_{country}$)
Technology-based products	Comtrade	*Advanced Technologies (AT) country share in global exports ('share')*	Share of a country's exports in each of the ATs/ all ATs combined in all global exports in the respective AT/ value is calculated also for all ATs combined (exports technologycountry/exports technologyworld)
Technology-based products	Comtrade	*Advanced Technologies country specialisation in exports ('specialisation')*	Share of each of the ATs/all ATs combined in a country's exports compared to their share in global exports
Technology-based products	Comtrade	*Advanced Technologies (AT) share in countries' exports ('significance')*	Share of a country's exports in each of the ATs/ all ATs combined in the respective country's total exports (exports technologycountry/exports totalcountry)
Technology-based products	Comtrade	*Trade balance (in % of trade volume)*	Difference between exports and imports in relation to the total trade volume (exports plus imports) of a country

Source: Consortium

4.2.2 Value chain indicators: Technology uptake

The level of uptake of advanced technologies has been measured based on a variety of sources such as the business survey, production indicators, text-mining of company websites and available Eurostat indicators.

The survey design and the analysis of online data is presented in detail in the subsequent chapter.

Employment data have been calculated based on the production data from Eurostat PRODCOM statistics multiplied with country and specific estimates for employment per euro of gross output (the inverse of productivity). The employment per euro of gross output for an advanced technology is estimated by the calculation of an average of the values of the respective sectors of advanced technologies using Eurostat Structural Business Statistics.

Table 3: Technology uptake indicators

Conceptual pillar	Source	Indicator	Description
Application	Survey	*Advanced Technologies Uptake (survey)*	Number of enterprises that integrated advanced technologies into their company operation or production
Application	Text-mining of company websites	*Advanced Technologies Uptake (webscraping)*	Firms that communicate about products and services enhanced by advanced technologies on their websites
Application	Survey	*Business Model Innovation*	Number of enterprises that declared to implement business model innovation as a result of technology uptake
Application	Survey	*Cost reduction*	Number of enterprises that declared any cost reduction as a result of technology uptake
Application	Survey	*Customer Satisfaction*	Number of enterprises that declared increased customer satisfaction as a result of technology uptake
Application	Survey	*Increase in # products/services launched*	Number of enterprises that declared increased number of products and services as a result of technology uptake
Application	Survey	*Product/Service Quality*	Number of enterprises that declared improved product/service quality as a result of technology uptake
Application	Survey	*Revenue and Profit Growth*	Number of enterprises that declared revenue and profit growth as a result of technology uptake
Application	Survey	*Time Efficiency*	Number of enterprises that declared improved time-efficiency as a result of technology uptake

Application	Eurostat	*eCommerce*	Share of sales from eCommerce in total turnover of firms
Application	Eurostat Community ICT usage	*Use of cloud computing services*	Share of enterprises using cloud computing services
Application	Eurostat	*Uptake of industrial robots*	Share of enterprises in manufacturing industry that use industrial robots
Application	Eurostat	*Use of Big Data analysis*	Share of enterprises analysing Big Data from any data source
Technology diffusion	PRODCOM/ Structural Business Statistics	*Advanced Technologies (AT) country share in global employment ('share')*[3]	Share of a country's employment related to the ATs/ all ATs combined diffusion in all global employment in the respective AT/all ATs diffusion combined ($empl\ techdiffsector_{country}/empl\ techdiffsector_{world}$)
Technology diffusion	PRODCOM/ Structural Business Statistics	*Advanced Technologies country specialisation in employment ('specialisation')*	Share of a country's employment related to the ATs/ all ATs combined diffusion compared to their share in global employment
Technology diffusion	PRODCOM/ Structural Business Statistics	*Advanced Technologies (AT) share in countries' employment ('significance')*	Share of a country's employment related to the ATs/ all ATs combined diffusion in the respective country's total employment ($empl\ techdiffsector_{country}/\ empl\ total_{country}$)
Technology diffusion	PRODCOM	*Advanced Technologies (AT) country share in global production ('share')*	Share of a country's production related to the ATs/ all ATs combined diffusion in the respective AT/all ATs diffusion combined ($prod\ techdiffsector_{country}/prod\ techdiffsector_{world}$)
Technology diffusion	PRODCOM	*Advanced Technologies country specialisation in production ('specialisation')*	Share of each of the ATs/all ATs diffusion combined in a country's production compared to their share in global production
Technology diffusion	PRODCOM	*Advanced Technologies (AT) share in countries' production ('significance')*	Share of a country's production related to the ATs/ all ATs combined diffusion in the respective country's total production ($prod\ techdiffsector_{country}/prod\ total_{country}$)

Source: authors

4.2.3 Enabling Conditions: Skills

Skills are a key asset of our economies and an enabler of technological transformation for SMEs and large companies. The monitoring of supply and demand for skills is key for policy makers at all levels (country, region, city) designing policies to attract and retain industry, talents and support the transformation of their economic sectors. At this moment there are however no indicators that provide metrics of skills supply and demand at a granular level i.e. linked with technologies.

On the supply side for instance, while ISCO (International Standard Classification of Occupations) codes are the best reference available in terms of workforce topologies, they are suitable and have been used to measure the availability of ICT skills but cannot at the moment be used to capture IoT or Cybersecurity related skills. Raw data from the International Labour Organisation would be needed to assess to what degree one could go further down in typologies granularity.

On the demand side for instance, CEDEFOP (the European Centre for the Development of Vocational Training) is designing indicators using 'online vacancies' for which data collection will potentially reach ISCO 4-digit level. ICT occupations will be covered but it remains uncertain how much of the advanced technologies will be possible to match with the ISCO codes.

Despite the above limitations, skills indicators by technology are among the new indicators proposed. We calculate indicators using Linkedin database by running queries by technology build with a set of predefined keywords by country. The keywords are based on literature, patent keywords used in the definitions and consultations with thematic experts. The indicators are described in the table below.

[3] Please note that the employment indicators have been included under Impact on the ATI data dashboard, although they are featured under technology diffusion in the methodological report in order to emphasise the link between employment patterns and technology diffusion.

Table 4: Skills indicators technology specific

Conceptual pillar	Source	Indicator	Description
Skills	LinkedIn	*Demand – Online Job vacancies*	Online job posts tagging advanced technologies skills in total online jobs by country
Skills	LinkedIn	*Supply – Professionals*	Share of professionals tagged by the advanced technology specific skill on their LinkedIn profile in total professionals on Linkedin by country applying a weighted method to correct for the representativeness of the sample

Source: authors

Table 5: Skills indicators non-technology specific

Conceptual pillar	Source	Indicator	Description
Skills	Eurostat	*Firms with ICT training*	Share of enterprises that provided any type of training to develop ICT-related skills of their personnel
Skills	Eurostat	*STEM graduates*	Graduates in tertiary education, in science, mathematics, computing, engineering, manufacturing, construction, per 1000 of population aged 20-29

Source: authors

4.2.4 Enabling Conditions: Investments

Investment indicators measure the financial resources invested in industrial modernisation such as R&D, new technologies or equipment. The set of indicators include both technology-specific and non-technological indicators. Two key indicators to measure investment per advanced technology are business R&D expenditure and venture capital investments.

Table 6: Investment indicators technology specific

Conceptual pillar	Source	Indicator	Description
Investment	Crunchbase and Dealroom merged dataset	*Last rounds of investment in advanced technologies*	Amount of total investment in companies developing advanced technologies aggregated for the period 2010-2019

Source: authors

Table 7: Investment indicators non-technology specific

Conceptual pillar	Source	Indicator	Description
Investment	Eurostat	*Expenditure for machinery & equipment*	Expenditure for machinery and equipment as a percentage of value added
Investment	Eurostat	*Business R&D expenditure*	Share of internal business R&D expenditure in value added
Investment	Eurostat, EU KLEMS	*Software expenditure*	Gross fixed capital formation in software and databases per value added

Investment	Eurostat, EU KLEMS	*Investment in ICT equipment*	Gross fixed capital formation of computing and communication equipment per value added
Investment	Eurostat	*Direct investment in the reporting economy (inward) in the information and communication sector*	The foreign direct investments (FDI) in the reporting economy (inward) in the information and communication sector are the investments made by foreigners in enterprises in the information and communication sector (sector J following NACE Rev. 2 classification) that are resident in the reporting economy in order to acquire a lasting interest (at least 10% of the voting power).
Investment	Eurobarometer	*Innovative public procurement*	The share of enterprises which sold innovative goods and services under public procurement contracts

Source: authors

4.2.5 Enabling Conditions: Innovation capacity

Innovation captures the introduction of new or improved products or processes. Innovation can either rely on own R&D efforts or be based on using or adopting others' knowledge. The indicators and data to be collected are based on the main Community Innovation Survey (CIS) indicators.

Table 8: Innovation indicators

Conceptual pillar	Source	Indicator	Description
Innovation	Eurostat CIS	*Product and/or process innovative enterprises*	Share of enterprises that introduced at least one product or process innovation within the previous three years
Innovation	Eurostat CIS	*Sales of new products and services*	Share of sales of product innovations in total sales
Innovation	Eurostat (CIS)	*Innovation expenditure*	Sum of total innovation expenditure of enterprises

Source: authors

4.2.6 Enabling Conditions: Infrastructure

Infrastructure refers to the physical infrastructure such as transport and communication networks and digital infrastructure such as broadband penetration.

Table 9: Infrastructure indicators

Conceptual pillar	Source	Indicator	Description
Infrastructure	Eurostat	*Transport infrastructure*	Average of motorway and railway potential accessibility
Infrastructure	Eurostat	*Broadband penetration*	Number of enterprises with a maximum contracted download speed of the fastest fixed internet connection of at least 100 Mb/s
Infrastructure	Eurostat	*4G coverage*	Percentage of populated areas coverage by 4G – measured as the average coverage of telecom operators in each country
Infrastructure	GSMA, https://www.gsma.com/	*Machine to machine communication, M2M SIM card penetration*	Part of the underlying infrastructure of the Internet of Things is machine to machine communication. GSMA tracks the number of M2M subscription

Source: authors

4.2.7 Enabling Conditions: Entrepreneurship

Entrepreneurship refers to the startup of new business activities but also to the scaling up firms to an economically efficient size. We measure this dimension by two main indicators notably by the startup birth and death rates of technology firms and by the scale-up rate.

Table 10: Entrepreneurship indicators

Conceptual pillar	Source	Indicator	Description
Entrepreneurship	Eurostat	*Startups birth and death rate*	*Share of technology firms birth and death rate*
Entrepreneurship	Eurostat	*Scale-up rate*	Share of employment in firms established in the past five years in total employment
Entrepreneurship	Global Competitiveness Index Ed. 2018	*Ease for startup entrepreneurs with innovative but risky projects to obtain equity funding*	Venture capital availability measure, based on a survey the ease for entrepreneurs with innovative but risky projects to find venture capital. The respondents answered the survey by rating the venture capital availability between 1 (extremely difficult) and 7 (extremely easy)
Entrepreneurship	Crunchbase and Dealroom merged dataset	*Number of investment-backed startups with AT*	Number of startups that develop the advanced technology and established after 2009

Source: authors

4.2.8 Enabling Conditions: Collaboration

Collaboration represents ways of interaction among firms or with other innovation actors. Other actors may include actors along the value chain, knowledge producing and disseminating actors (e.g. universities, research institutes) and public actors (governments, agencies).

Table 11: Collaboration indicators

Conceptual pillar	Source	Indicator	Description
Collaboration	European Cluster Observatory	*Specialisation in clusters of emerging industries*	Number of enterprises in emerging industries per total number of enterprises
Collaboration	EPO	*International co-inventions*	International co-inventions in themes relevant for industrial modernisation per population
Collaboration	Eurostat	*Innovation cooperation*	Share of enterprises cooperating with others on innovation

Source: authors

4.2.9 Impact: Industrial Modernisation Performance

The indicators

Productivity

A question for the impact of industrial modernisation is to what extent new technologies are used by economic actors in an efficient manner and whether they help raise economic welfare or not. For that purpose, productivity is a well-accepted economic indicator. However, it is usually measured on aggregate or sectoral level and not on a technology level. In the previous KET Observatory phases sectoral productivities were used by weighting them by the KETs intensity and taking the inverse for calculating employment. However, these are rather poor proxies of productivity for KETs and would also be for digital technologies as they mostly express whether the technologies are adoptive in sectors with high productivity, but hardly whether there is a high productivity in KETs generation and diffusion.

Table 12: Performance – Productivity

Conceptual pillar	Source	Indicator	Description
Performance	Eurostat	*Labour productivity*	Based on gross output (total turnover)

Source: authors

Growth

Table 13: Performance – Growth

Conceptual pillar	Source	Indicator	Description
Growth	Eurostat	*Change in manufacturing share in value added*	Change over time in gross value added in manufacturing per total gross value added
	Eurostat	*Change in real value added*	Growth rate of value added at factor costs
	Eurostat	*Job growth in manufacturing*	Growth rate of numbers of persons employed in manufacturing
	Eurostat	*Growth of role of industrial services*	Growth of role of industrial services
	OECD	*Growth of value added in exports*	Growth of value added in exports

Source: authors

Sustainability

Table 14: Performance – Sustainability

Conceptual pillar	Source	Indicator	Description
Sustainability	Eurostat	*Change in energy intensity*	Change in energy consumption per value added
	Eurostat	*Environmental process innovation*	Enterprises that introduced an innovation with environmental benefits obtained within the enterprise per all enterprises
	Eurostat/Eco-innovation observatory	*Firms with environmental innovations*	Firms declaring to have implemented innovation activities aiming at a reduction of material input per unit output (% of total firms)

Source: authors

Section 5

5. Patent, trade and PRODCOM analysis

5.1 Defining advanced technologies in terms of IPC Codes

In order to define advanced technologies in terms of IPC codes a multi-layered strategy was applied. For the 6 key enabling technologies covered by the former KETs Observatory, the original definition was used as a basis. This definition was checked for updates in the International Patent Classification (IPC) and adjusted accordingly. Therefore, the KETs definition follows the original specification to remain consistent with earlier studies, the update only includes technical adjustments.

For the digital technologies of the Digital Transformation Monitor, we based our definitions on earlier results from the scientific literature as well as earlier classifications from Fraunhofer ISI that were generated in cooperation with respective technology experts at the institute. Several classifications from different sources were tested and (randomly) manually checked to be able to choose a definition that a) reflects the respective technology, b) delivers most timely results and c) delivers a significant number of observations for further analyses. Therefore, we concentrated on definitions based on IPC classes or combinations of keywords and IPC classes.

As in the case of the KETs, these definitions were updated alongside the current version of the IPC to address changes in the IPC classification over time.

Table 15 provides in-depth information of the sources for the respective classifications. Regarding the fields Augmented/Virtual Reality, Blockchain, Cloud computing no patent classes were assigned as the mentioned fields can be seen as 'pure' software fields, for which patents cannot be filed at the EPO.

Table 15: Overview of the classifications for digital technologies

Field	Source
Artificial Intelligence	OECD
IT for Security	OECD (Inaba/Squicciarini 2017)
Big Data	OECD (Kiseleva/Palali/Straathoof 2016)
Internet of Things (IOT)	Classification by Fraunhofer ISI
IT for Mobility	Classification by Fraunhofer ISI
Robotics	Classification by Fraunhofer ISI

Source: authors

A brief overview of the assessment of relevance of patent indicators and the availability of digital technologies definitions (IPC codes) is provided in Table 16.

Table 16: Patent indicators for advanced technologies – assessment and proposed codification

Advanced technology	Assessment	Definitions – codification
Advanced Materials	Include patent indicators	• KETs observatory definition • Technical update of IPC codes
Advanced Manufacturing technologies	Include patent indicators	• KETs observatory definition • Technical update of IPC codes
Industrial Biotechnology	Include patent indicators	• KETs observatory definition • Technical update of IPC codes
Micro and Nanonelectronics	Include patent indicators	• KETs observatory definition • Technical update of IPC codes
Nanotechnology	Include patent indicators	• KETs observatory definition • Technical update of IPC codes
Photonics	Include patent indicators	• KETs observatory definition • Technical update of IPC codes
Artificial Intelligence	Include patent indicators	• Fraunhofer-ISI definition. (building on OECD and EPO work)[4]

[4] Baruffaldi, S., et al. (2020), "Identifying and measuring developments in Artificial Intelligence: Making the impossible possible", OECD Science, Technology and Industry Working Papers, No. 2020/05, OECD Publishing, Paris, https://doi.org/10.1787/5f65ff7e-en.

IT for Security	Include patent indicators	• Fraunhofer-ISI definition
Augmented Reality/ Virtual Reality	Exclude patent indicators	• Minimal hardware (in terms of value) associated with AR/VR – much of the value is in software
Big Data	Include patent indicators	• Fraunhofer-ISI definition. (building on UKIPO work)
Blockchain	Exclude patent indicators	• Built mostly around software and specific transactions, so less patentable • Some organisations have specific patents relating to ideas but these are more general and not exclusively applicable to Blockchain
Cloud computing	Exclude patent indicators	• Much of cloud technology is storage or provision of remote computation so any patents relate to storage or processing, not specifically for its use in cloud • Currently it is limited to few patents by some large players that provide the solutions e.g. IBM.
IoT	Include patent indicators	• Fraunhofer-ISI definition (building on Near Field Communication (NFC) as one measurable part of IoT)
IT for Mobility	Include patent indicators	• Fraunhofer-IS definition. • Includes parts of Mobility with a clear technology component • Scoping resulted from Mobility expert consultations
Robotics	Include patent indicators	• Fraunhofer-ISI definition

Source: authors

5.2 Defining advanced technologies in terms of PRODCOM Codes

Production data is analysed in two ways: (i) related to a **technology generation and exploitation approach and (ii) a technology diffusion approach.** The technology generation and exploitation approach refers to the production data that can be associated in whole or in a dominant part with the respective digital technology or KET. Categories of production data should aim to be exclusively associated with each technology; however, it is acknowledged that some overlap between the technologies may occur, which was the case already in the KETs Observatory Phase I and II. The technology diffusion approach refers to the production data that is highlighting to what extent the EU can use the potential of KETs to improve its competitiveness by manufacturing KETs based products and applying them in the production of manufacturing goods.

At the level of the **technology generation and exploitation approach**, a distinction is made in the process steps for the digital technologies and the KETs.
The **process steps for the KETs** were as follows:

- Obtainment of the final list of KETs PRODCOM codes used in KETS Observatory Phase II
- Assessment of their relevance reflecting recent technological trends
- Assessment of changes to the PRODCOM codes for the years 2016 and 2017 (latest data)
- Exchange with Eurostat (both the initial lists and the changes) for the calculation of the technology generation and exploitation indicators following the same approach as outlined in the KETs Observatory Phase II.

The following **key process steps for the digital technologies** were as follows:

1. **EU analysis using PRODCOM data**: 2018 PRODCOM codes were obtained to carry out the selection of the relevant codes. PRODCOM data are available for EU24 and UK.
2. **Identification of keywords**: based on the definitions of each digital technology, a set of keywords were developed upon which to analyse the PRODCOM code descriptions (please see Appendix E).
3. **Assignment of PRODCOM codes** to the digital technologies independently per technology, codes were assigned to AI, IT for Security, Connectivity, Mobility, Robotics, IoT and Big Data.
4. **Consideration of production volumes:** In connection with the previous step, it was important to also include the production volumes for each PRODCOM code in order to understand the importance and relative weight of an individual code in relation to the overall total for the respective technology and its relative importance.
5. **Joint alignment:** a joint alignment of the terminology and logic of selection for Harmonised System and PRODCOM codes was carried out. In general, the objective was to have the same decision with respect to the codes selection or exclusion reflected across the various data sets. This was an essential step involving several iterations between experts from the respective teams. A series of sub steps included:
    a. **Sharing initial selections:** initial lists of selected codes were jointly shared in order to enable a first alignment. Based on a first assessment, it was determined that a detailed and code specific alignment would be needed.

   b. **Development of a joint data set:** In order to enable the alignment, a merged list with indications of the codes from each data set was developed. The development of this list included the step of translating HS codes that were present also from an IPC perspective, but also an HS perspective into PRODCOM codes, and vice versa. Through this alignment, the initial list of PRODCOM codes was enlarged. Records of the changes were kept.
   c. **Refinement:** A joint expert discussion was organised to refine the results of the lists.
6. **Finalisation / validation:** as a final step, data sets were cleaned and prepared to be shared with the Commission and Eurostat for review and input towards finalisation of the selection.
7. **Execution of calculations**: The final step comprises the calculation of the digital technologies by Eurostat, including the production share, the specialisation and the share in total production.

At the level of the **technology diffusion approach**, a distinction is made in the process steps for the digital technologies and the KETs.

The selection of PRODCOM codes was initially made at the time of the KETs Observatory Phase I, with minor updates in the KETs Observatory Phase II. Given the evolution and uptake of technologies in the meantime, but also changes in their availability, as well as possible developments, it has been deemed meaningful to revisit the initial selection to update it based on current production data classifications (2018).

In order to carry out this step, it was necessary to revisit the 2012 list of KETs and bring it up to date. This involved updating the development of PRODCOM classification to the year 2018, tracking and updating any previous codes to their current nomenclature. Once updated, all newly developed codes that reflect the latest developments were added. An expert assessment of the codes per technology based on the latest versions of the PRODCOM data was then carried out.

While the KETs Observatory Phase I and Phase II developed a list of PRODCOM codes for the technology diffusion approach for all six KETs, the ATI project brings in digital technologies for which the list of PRODCOM codes still needed to be compiled, which ideally should be aligned with the approach applied for the KETs. Starting from the premise that - different from KETs such as Industrial Biotechnology and Advanced Materials, digital technologies do affect close to all sectors, it became apparent that the approach used in the previous KETs Observatory Phases needed to be revisited, especially also to incorporate the digital technologies.

A keywords-based approach was envisaged in order to identify the application areas for the technology diffusion approach and apply these to select the PRODCOM codes.

We departed from the keywords identified in other parts of the ATI project like LinkedIn keywords, the IPC codes, as well as the ATI survey. As a next step, various sources were screened to develop specific keywords relating to each of the digital technologies and targeting application areas for these technologies. These sources include key studies such as the AI Watch – Defining Artificial Intelligence, and the work on Strategic Value Chains (SVC) of the Strategic Forum for Important Projects of Common European Interest (IPCEI)[5] as well as the European Cybersecurity Centres of Expertise Map - Definitions and Taxonomy. The resulting application areas and subdomains, and their associated keywords are presented in Appendix E.

A final step to translate these keywords into production data terminology was carried out, resulting in PRODCOM data adjusted terms. These terms were matched with the PRODCOM data to come to a resulting list of matched codes.

5.3 Defining advanced technologies in terms of HS Codes

As with the PRODCOM codes, it is conceptually challenging to define key enabling technologies and - more so - digital technologies in terms of HS commodity groups (Harmonised Commodity Description and Coding Systems), since a large element of what constitutes and distinguishes them are - by definition - not commodities but software components and algorithms. Still, no software can be effective without relevant hardware that is in certain, specific ways particular to the concrete technology under consideration. In the following, our definition is based on this premise of 'specifically embedded software', defining e.g. different groups of typical commodities that are required to establish Big Data, Mobility or Cybersecurity solutions respectively.

For the Key Enabling Technologies, earlier projects (KETs Observatory) had already defined a range of HS2007 codes which, at the time, had been reviewed by a number of experts and – upon renewed internal review did not display any signs of having become outdated. Also, the HS2007 definitions could still be used on current data as COMTRADE microdata remain classified both by HS2012 and HS2007 at

[5] https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=3583

this point in time. Thus, using the existing definitions ensures a best possible degree of continuity and comparability with the earlier KETs Observatory.

For the digital technologies, new definitions had to be developed without any pre-existing reference. The process of defining them followed a two-step process based on a double strategy. First, existing IPC definitions of the digital technologies were transformed into HS definitions based on a published methodology[6] developed expressly for this purpose. Second, initial PRODCOM definitions that had been developed in parallel were translated into HS codes using keyword searches in HS databases. Such an identification of matching PRODCOM and HS codes for relevant commodities is often, even if not always, possible as their descriptions are comparatively similar in wording. The findings of both exercises were merged and duplicates removed. In the following, all codes were subjected to manual inspection and, where needed, normalised by experts. Commodities of which quite obviously only some smaller element was related to the technology area in question were removed (e.g. photocopiers). Subsequently, overall EU-level trade and production volumes were calculated for all relevant codes under consideration. Commodities that displayed either a very high trade volume or a very high production volume and at the same time a tendency to appear in all groups (e.g. computer chips) were very specifically normalised and in most cases either allocated to one specific group or to none at all. Each particular commodity was discussed in detail to establish a logical link with a particular group in the initially mentioned sense. PRODCOM and HS definitions were developed jointly by the teams of Fraunhofer ISI and IDEA in an iterative process so that both can be considered conceptually integrated and comparable in future analysis.

[6] Lybbert, T.J., Zolas, N.J. (2014): Getting patents and economic data to speak to each other: An 'Algorithmic Links with Probabilities' approach for joint analyses of patenting and economic activity, Research Policy 43, 530-542. (including detailed documentation in separate files)

6. Collection of primary data: survey

6.1 Survey Methodology

The ATI business survey conducted in 2019 was a telephone survey of 11 countries across Europe, using those countries that represent best the anticipated adoption of new technologies. The survey focused on a single high-level decision maker that covers adoption of the advanced technologies within their organisation. The following quotas ensured representation of each of the countries, size bands and industries based on the share each industry and size band occupied in the number of companies within that band or industry.

Table 17: Quotas for the 2019 survey

Country	#	Industry	#	Size Band	#
France	100	Finance	85	10-249	350
Germany	100	Gov/Edu	85	250-499	250
Italy	100	Healthcare	85	500-999	150
Netherlands	100	Manufacturing	210	1,000+	150
Spain	100	Professional Services	110		
United Kingdom	100	Retail, Wholesale	110		
Denmark, Sweden	100	Telecom, Media	65		
Czechia, Hungary, Poland	200	Transport, Accommodation	85		
		Utilities, Oil, Gas	65		

Source: authors

With this sample (900 companies), the confidence intervals are the following:

- Western Europe Countries – 10%
- Denmark/Sweden – 10%. (Denmark or Sweden – 14%)
- Czechia/Poland/Hungary – 7%, (Czechia or Poland or Hungary – 17%)
- All Countries – 3.3%.

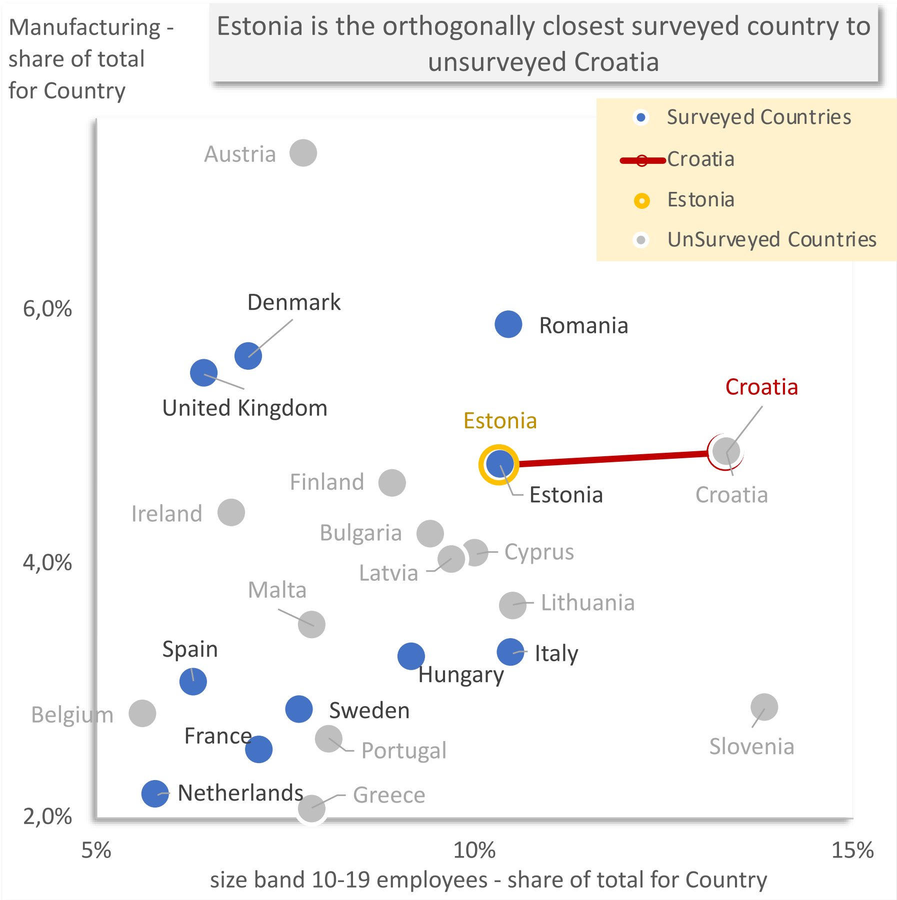
Representation share for each industry was calculated from a combination of IDC industry and size band representation and Eurostat data for the number of companies by industry and size band.

Un-surveyed countries representation

This research surveyed a limited number of EU Member States in the interest of time and cost – as surveyed countries represent the EU as a whole. Multi-dimensional representation of each country was used to map un-surveyed countries to the most representative country surveyed using 18 dimensions covering industry share, size band share and high-level education for each country. Un-surveyed countries were compared using this vector in 18-space to find the closest orthogonally distant equivalent country, minimising the distance between the un-surveyed country and the representative country.

The nearest surveyed country to Croatia (an un-surveyed country) is Estonia – and the relative distance in the two dimensions are included calculations (see Figure below). While in the figure this is evaluated only over the two dimensions of Manufacturing's share of all industries and 10-49 size band share of all size bands to give an indication of how this process works, the actual model uses all 18 dimensions in its evaluation of the 18-space vector difference.

Figure 2: Nearest neighbour selection representation in 2D for unsurveyed countries



Source: authors

In a similar fashion, the ATI survey was repeated between September and November 2020 with some modification and improvements in the sample size and in the methodology. The second ATI survey was in fact conducted among 1 547 organisations with more than 10 employees covering seven EU Member States, i.e. Denmark, France, Germany, Italy, Poland, Spain and Sweden.

Table 18: Second ATI Survey: Sample structure by country, industry and size-bands

Country	#	Industry	#	Size band	#
France	311	Financial Services	171	10-249	464
Germany	303	Government/Education	167	250-499	334
Italy	279	Healthcare	130	500-999	345
Poland	165	Manufacturing discrete	120	1 000+	404
Spain	281	Manufacturing process	154		
Denmark	80	Professional Services	187		
Sweden	128	Retail, Wholesale	161		
		Telecom, Media	116		
		Transport, Logistics	130		
		Utilities, Oil, Gas	111		
		Agriculture	100		

Source: authors

The eligible respondents for the second ATI survey were individuals best qualified to answer questions about overall ICT, digital and technology strategy and activities. A set of screening questions were used to determine'respondents' eligibility. As a result, eligible respondents were most likely senior decision-makers responsible of these strategies and activities. Interviews were conducted through a web-based platform (CAWI – Computer-Aided Web Interviews), as well as via a Computer-Aided Telephone Interviewing (CATI) system, thus ensuring wide reachability, swiftness in data collection, high quality and accuracy of responses. Both CAWI and CATI systems were endowed with various automatic data checks and skip patterns, which occurred while the respondent remained connected on the web platform or on the telephone line. The survey was conducted in the respondents' native language.

The company (or organisation) has been selected as the sampling unit. As with the first ATI survey, in this second survey a 'company' refers to a legal or social entity, or a group of entities, that engage(s) in activities and transactions (such as the purchase of IT goods and services) in its/their own right. A company must have sole ownership or control. It can be heterogeneous with regard to its economic activity and location. It has legal, administrative or fiduciary arrangements; organisational structures; or other parties with the capacity to efficiently allocate resources to achieve objectives. Examples include corporations, non-profit institutions and government agencies. When the enterprise is a single-location organisation, the concepts of 'company' and 'local unit/establishment' coincide.

Survey quotas were defined by country, vertical/sector and size. Seven countries were surveyed. The sample consisted of 80 interviews from Denmark, 311 interviews from France, 303 from Germany, 279 from Italy, 165 from Poland, 281 from Spain and 128 from Sweden. As a comparison, in the first 2019 ATI survey, the sample consisted of 50 interviews from the Czech Republic, 50 from Denmark, 100 from France, 100 from Germany, 60 from Hungary, 100 from Italy, 100 from the Netherlands, 90 from Poland, 100 from Spain, 50 from Sweden and 100 from the United Kingdom.

Sample interviews were established also by vertical market and company size. Vertical markets were defined according to the European Classification of Economic Activities (NACE) Rev. 2 coding system. The survey classified 17 vertical markets/industries, for analysis purposes they have been grouped into eleven aggregated verticals based on sample size and industry segment. Results are therefore provided for the following eleven verticals: Finance, Government/Education, Healthcare, Discrete Manufacturing, Process Manufacturing, Professional Services, Retail/Wholesale, Telecom/Media, Transport, Utilities/Oil & Gas, Agriculture. Company sizes were based on the number of employees and aggregated into the following segments: 10–249; 250–499; 500–999; and 1 000+ employees.

The sample frame was obtained from a list source representative of the entire local market, regardless of computerisation. List sources grouped vertical markets/industries according to standardised industries (based on NACE codes). A predetermined number of interviews were completed in each of the four company sizes and eleven vertical market aggregates to ensure reliable and robust results at 95% confidence interval for each size and industry group.

Confidence Intervals

For this second ATI survey, the confidence interval at 95% was confirmed. A 95% confidence interval defines a range of values that captures the true mean of the population with a 95% likelihood. The larger the sample, the higher the likelihood that the mean of the sample is closer to the mean of the population so the confidence interval will be narrower. The detailed interval of confidence for each surveyed country is offered in the Figure below.

Figure 3 Confidence intervals by country (Total, Western EU, Central and Eastern EU; Number of Respondents)

Country	**N=**	**Margin of Error +/-%**
Denmark	80	11.0%
France	311	5.6%
Germany	303	5.6%
Italy	279	5.8%
Poland	165	7.6%
Spain	281	5.8%
Sweden	128	8.7%
Nordics	208	6.8%
CEE	165	7.6%
WE	1382	2.6%
TOTAL	**1500**	**2.5%**

Source: ATI, Advanced Technologies for Industry, Survey, November 2020

Considering a 95% confidence level, the margin of sampling error for the entire ATI survey sample is ±2.5%. In other words, if 50% of respondents say they are investing in a new technology, then there is a 95% chance that adoption for this new technology for the true population is between 47.5% and 52.5%. That means that, if the same question was asked again and again to different samples, the confidence interval from 47.5% to 52.5% will match the results from the actual population 95% of the times. Confidence intervals for specific questions may vary due to variations in sample size, such as when analysing results at the vertical market level, or for filtered questions.

Section 7

7. Collection of primary data: text-mining of online content of company websites

Analysing content available through the web has recently become a popular new way to get more insights into trends and areas where the traditional statistical approaches fail to provide reliable and timely information. Today, most of the companies across European countries and regions maintain a website, leave a 'digital footprint', communicate about their activities and inform their customers about their products and services through online content, hence analysing these texts is a promising way to get a better understanding about certain transformational aspects as well.

Information extracted from business websites can help address the gap of traditional indicators in the evidence base, generating timely and relevant information about the diffusion and uptake of advanced technologies such as those we want to measure in this project. The reason for their relevance is intuitive: websites are an important marketing medium for businesses. Many businesses that adopt advanced technologies to differentiate themselves from competitors will desire to announce this as a signal of their innovative capabilities and quality or efficiency advantages, and to attract talent with relevant skills. For this same reason, they have incentives to keep this information up-to-date.

There is a growing body of research using these methods. Gök, Waterworth & Shapira's analysis of providers of green business shows that business websites are more suitable for studying R&D activities further downstream than patents and publications (Gök et al., 2014). In follow-on work, this approach is scaled up to identify and analyse the green industries in the UK (Shapira, Gök, Klochikhin & Sensier, 2014), and to analyse the introduction of new products using the graphene Nanotechnology (Shapira, Gök & Salehi, 2016). Nathan & Rosso use, on their part, business websites to measure digital technology industries in the UK. Their analysis reveals a significantly larger number of digital businesses than official statistics precisely because their methodology is able to identify businesses using digital technologies to provide goods and services in other sectors (such as for example a fintech company or a Big Data analytics company operating in retail) (Nathan & Rosso, 2015).

More recently, a study on the immersive economy in the UK identified companies developing or using augmented and virtual reality technologies through mentions in their website (Mateos-Garcia et al, 2018). One interesting aspect of the immersive economy analysis is that it used a combination of the business website data with a survey in order to generate population estimates about important variables such as the share of turnover generated from immersive technologies which were not easily accessible from the scraped websites, along the lines of Guzmán and Stern's 'nowcasting' and 'placecasting' of entrepreneurial activity in the USA (Guzman & Stern, 2016). Recent work in Germany has used a similar approach, scraping the websites of the population of UK businesses and matching it with Germany's Community Innovation Survey in order to identify features of websites that are highly predictive of whether a business is innovative or not (Kinne & Axenbeck, 2018; Kinne & Resch, 2018).

Although our brief overview of the literature suggests that business web-scraping could make a valuable contribution to the measurement of advanced technology uptake and diffusion in this project, it is 29ormalizertant to recognise that this data source (like any others) is not without limitations. We outline them in turn, drawing on our own experience using this kind of data.

First, there is the issue of potential sectoral and geographical biases: the level of website adoption is not homogeneous across EU countries and sectors and this could create biases. It is anticipated that there is a slight over-representation of digital sectors and of urban dense areas where those sectors tend to cluster.

Second, there is the issue that, notwithstanding its ability to capture downstream innovation activities better than alternative sources, it is still the case that web data will in general be better at capturing the incorporation of technologies into products and services that a business seeks to promote through its website, than their incorporation into processes (where the business may have low incentives to disclose adoption or might even have disincentives to disclose it in order to prevent imitation). Another related bias is that businesses could have incentives to exaggerate their levels of adoption of certain technologies, or relabel the technologies that they use (for example, referring to traditional analytics methods as 'AI') in order to increase their attractiveness and visibility. As the information that firms post on their websites is self-reported, results have to be interpreted with caution and keeping in mind the motivations of firms to communicate about a technology.

In the ATI project, website data have been accessed using a webscraping programme and using text-mining methodologies in order to identify mentions to the technologies of interest. Technopolis Group and its partners created a database of webscraped business URLs in the framework of the 'Study on the potential of servitisation and other forms of product-service provision for EU SMEs[7]' that has been further extended to cover a larger population of European firms. The sample of webscraped company websites includes data for 13 EU countries.

Table 19: Company coverage in the existing sample

Country	Number of companies covered in the dataset	Number of enterprises (all companies) in the Structural Business Statistics in manufacturing (C code) in 2017	Share of manufacturing companies in the country, covered by the final sample
Austria	9453	25477	37%
Belgium	652	36801	2%
Bulgaria	3526	31272	11%
Czechia	17350	175894	10%
Denmark	5060	15343	33%
France	24611	197657	12%
Germany	44600	190541	23%
Hungary	6261	50809	12%
Italy	52567	383585	14%
Latvia	1702	10921	16%
Netherlands	11940	66662	18%
Poland	26237	198757	13%
Spain	20920	168717	12%

Source: Technopolis Group

The webscraping of corporate websites included the implementation of the following steps:

1. Process the data: clean and normalise the data.
2. Prepare the semantic engine, design and tune the algorithm: the semantic engine and the language model were adapted based on pre-developed keywords.
3. Tune the algorithm for each pair language and advanced technology order to minimise the risk for certain concepts/keywords to be much more significant for a given language (hence having a greater weight) with respect to another language.
4. Create a list of keywords in the respective languages of countries in order to capture the use of technologies or offer of products and services based on advanced technologies (please see Appendix F).
5. Manually test the signals returned by the algorithm which can help minimise false positives and false negatives through several iterations.
6. Label the data with categories of interest.

We brought together data in the languages of multiple EU Member States and dealt with this heterogeneity by translating all the seed vocabularies for the advanced technologies, functions and industries using automated systems such as Google Translate and manually validating the results.

As a result of the webscraping of company websites and text-analysis, we constructed the indicator entitled 'Share of companies that reference the use of advanced technology'. Not all advanced technologies could be included in this analysis since some of the technologies are not adequately

[7] https://op.europa.eu/en/publication-detail/-/publication/0d1ed8aa-8649-11e8-ac6a-01aa75ed71a1/language-en

represented on company websites. The advanced technologies that are covered include: Advanced Materials, Artificial Intelligence, AR/VR, Big Data, Blockchain, Internet of Things, Micro- and Nanoelectronics, Nanotechnology, Photonics and Robotics. In some industry-specific cases, Industrial Biotechnology, and Advanced Manufacturing (specifically for 3D printing) have been included in the analysis.

Section 8

8. Collection of primary data: LinkedIn analysis

8.1 Overview

Skills indicators for ATI have been constructed based on data sourced from the LinkedIn 'Talent Insights' tool. To harvest the data from LinkedIn, keywords capturing skills by advanced technology have been defined and reviewed by technology experts. Queries have subsequently been constructed to filter the database by location and industry.

The keywords used for each advanced technology are listed in Appendix D. Keywords are a result of a long reflection and tests where some words had been excluded either because they led to false positives or because they were not available in the LinkedIn database. The keywords are distinct by technology and there are no overlaps except for Advanced Manufacturing which encompasses keywords related to the use of Robotics and Advanced Materials in manufacturing

LinkedIn data are downloaded continuously each month since December 2019 until June 2021 in order to monitor the development of skills supply and demand for a longer time period.

The two core indicators are related to skills supply and skills demand. The methodological steps to arrive to an indicator on skills supply are described below:

1. Source the data from LinkedIn using keywords in multiple moments in time within a year making each time a snapshot of the availability of the skillset corresponding to the technology in focus and the total number of LinkedIn users;
2. Calculate a share of individuals with the skillset corresponding to the technology in focus in total individuals with a LinkedIn account;
3. Create an average for the period considered;
4. Conduct the representativeness analysis;
5. Correct the results by the application of weights.

The methodological steps to arrive to an indicator on skills demand are described below:

1. Source the data from LinkedIn using keywords in multiple moments in time within a year making each time a snapshot of the availability of online job vacancies corresponding to the technology in focus and total online job vacancies in the LinkedIn database;
2. Calculate a share of online jobs vacancies requiring the skillset corresponding to the technology in focus in total online jobs vacancies available in LinkedIn;
3. Create an average for the period considered;
4. Conduct the representativeness analysis: LinkedIn has globally 20 million and more active daily job posts, which positions it among the largest online job engines in the world. The jobs data includes both jobs posted directly on LinkedIn via LinkedIn Jobs as well as jobs ingested from over 40 000 sources including company websites, applicant tracking systems, job boards, aggregators and job feeds. LinkedIn has developed advanced algorithms to identify and remove duplicate job posts from ingested sources. This process should ensure that it reflects the current state of the job market. Comparisons with the work Cedefop has been conducting on online job vacancies can be made as soon as results are obtained.

For the calculations of the indicators, the following is important to note:

- Skills are identified from fields including profile summary, job title, job description and field of study. Results hence include individuals with skills in the technology in focus who may however not be practicing the skills in their professional activity neither currently nor in their past occupations.
- It should be noted that to go from education to a skill LinkedIn uses machine learning technology to standardise fields of study, similar to the standardisation for job titles & skills.
- LinkedIn's job title & skill standardisation algorithm includes translation from Arabic, Czech, Danish, German, English, Spanish, Finnish, French, Italian, Japanese, Korean, Dutch, Norwegian, Polish, Portuguese, Russian, Swedish, Turkish, Chinese. This means that a search will return job titles/skills that were entered in any one of those languages, regardless of the search language.

- LinkedIn algorithms are used and there is no possibility to perform any in depth quality assurance.

8.2 Weighting approach

The representativeness of the LinkedIn database has been assessed through various criteria presented in Appendix D. In order to derive correct estimates of population parameters (as measured by Eurostat), given that the LinkedIn sample departs from the distribution of population characteristics, a poststratification method has been used by incorporating population distributions of variables into the LinkedIn estimates. The post stratification technique has been implemented by dividing the LinkedIn sample into post-strata and compute a post-stratification weight to account for the under or over represented groups in the population. More specifically, the following process has been followed to construct the algorithm:

1. Population characteristics which are deemed important have been identified: These include i) country (27 levels: EU 27 countries), ii) gender (two levels: male and female) and iii) field (two levels: ICT specialists and Human Resources in Science and Technology).
2. Each characteristic formed a stratification variable and the combinations of the stratification variables formed the study strata.
3. The total number of people within each stratum (*stratum count* – N_h) were downloaded from Eurostat.
4. The *stratum weight* $W_h = \frac{N_h}{N}$ was calculated by dividing the stratum count with the total number of people (N) in all strata from Eurostat.
5. The total number of people in each sample stratum (n_h) was recorded from LinkedIn.
6. The sample stratum relative size $w_h = \frac{n_h}{n}$ was calculated by dividing the LinkedIn stratum count with the total number of people (n) in all strata from LinkedIn.
7. The total number of people in each sample stratum possessing skill x (x_h) was recorded from LinkedIn.
8. A first estimate of the index for each skill x was derived as $I_{hx}^{init} = \frac{x_h}{n}$.
9. The final estimate of the population value of the index (adjusting for the true distribution of the population into the strata) was calculated as $I_{hx} = I_{hx}^{init} \cdot \frac{W_h}{w_h}$.
10. In order to derive the value index (as a percent of the total EU27 population) for the desired aggregation levels i.e. country and field and EU27 and field the weights were aggregated accordingly.
11. In order to derive estimates of the indices within each country, steps 6 through 10 were repeated separately for each country.
12. The index values obtained represent the shares of professionals with skills in each advanced technology in ICT, and Science and Engineering.

9. Analysis of investment and company data: Crunchbase and Dealroom

Primary data on venture capital and private equity investment in innovative startups and firms have been sourced from Crunchbase and Dealroom databases. Both databases consist of a sample of innovative, investment-backed technology active companies in the EU27 and competing economies such as the US.

With the objective to have a more robust sample and better data coverage for the EU27, the datasets of Crunchbase and Dealroom have been merged, notably the information on venture-backed tech companies, their average total and last investment, year of foundation, type of investment and activity and industry description. Crunchbase data was matched with Dealroom data, using the names of the companies as a common identifier. The companies' names do not indicate any differences in Crunchbase and Dealroom, but additional cleaning of the data was necessary. Duplicate companies were removed from the sample.

Crunchbase is a widely trusted source of information on venture capital backed innovative companies. Dealroom is a provider of similar type of information in Europe having a better coverage about tech startups and scaleups in the EU27. Crunchbase information includes investments and funding information, founding members and individuals in leadership positions, mergers and acquisitions, news and industry trends. Originally built to track startups, the Crunchbase website contains information on public and private companies on a global scale. Crunchbase sources its data in four ways: through a venture programme, machine learning, an in-house data team and the Crunchbase community. Members of the public can submit information to the Crunchbase database. These submissions are subject to registration, social validation and are often reviewed by a moderator before being accepted for publication.

Dealroom is an online-based platform that provides business information about innovative organisations and their investment stages from seed-stage to late growth-stage. It enables investors to track companies' progress and decide the appropriate time to invest in them. Nevertheless, it is increasingly used in studies for economic research as well. It is particularly used as a source of information on startup activity and financing within and across countries as well as regions. It covers 77% of information in comparison with the official statistical evidence. In comparison with Crunchbase data source, the Dealroom platform covers 30% more organisations for EU countries. The relevant information for this study that are included in the database are listed in the table below.

Figure 4: Overview of Crunchbase information

Company information	**Financing information**
• company information risk financing information • company size class • location (country, city and region) • primary role (firms, group, investor, university and other), status (operating, acquired, IPO or closed) founding date • dates of the record • category (classification in terms of main activities of the organisations such as industry) • social media information	• amount of capital involved • number of investors involved • type (e.g. VC, business angel, private equity) • profit/revenue information for 4 last years

Source: Technopolis Group

Figure 5: Comparison of Crunchbase and Dealroom information

Captured information	Crunchbase captures 650 000 individuals, 900 000 organisations, over 200 countries	Dealroom captures +1 000 000 companies, 85 000 investors, +400 funds

Source: Technopolis Group based on information obtained from Crunchbase and Dealroom

Crunchbase has been explored by several scholars including the OECD to reflect about innovative startups and venture capital investment. Although the coverage of Crunchbase varies across countries and technology oriented sectors are much better covered, it is one of the most popular databases to analyse entrepreneurial behavior.

Since Crunchbase is more and more recognised as a primary data source for investors, entrepreneurs have an incentive to register on the website (Breschi et al., 2018). It is based on a crowd-sourcing process, where registered users can complement and revise information not just on their own profiles but suggest further information to be included on other profiles too. Following Breschi (2018), comparisons with other sources suggest that the coverage of Crunchbase is quite comprehensive for startups. When comparing the coverage of Crunchbase to the OECD Entrepreneurship Financing Database, the results show similarity across the two data sources. The share of investments accounted for the United States appear comparable across the two sources (Dalle et al. 2017).

According to Crunchbase the total number of organisations included in the database was 900 000 in February 2019 with a total funding rounds of 300 000.

Share of companies by continent is the following:

- 51% North America (US, Canada)
- 28% Europe
- 15% Asia.

The dynamic development of Crunchbase is also reflected in the fact that according to Dalle et al. (2017) the database downloaded in January 2017 contained information on more than 490 000 distinct companies located in 199 different countries. 3 years later, the coverage has been almost doubled.

Merging Crunchbase with Dealroom resulted in a higher coverage of startups active in the EU27. Our estimate is that the coverage has been increased with a further 10%, however the US remained more representative than the EU27. This has to be kept in mind when interpreting the results of the analysis.

In order to capture firms involved in the development or active deployment of advanced technologies (e.g. AI-driven medical device), we relied first of all on the industry categorisation of Crunchbase and tagging system of Dealroom. The selected list of categories and tags are listed in Appendix G. Besides the categories, we performed a manual cleaning and checks with the help of text-mining the business descriptions included in both databases. In the case of Industrial Biotechnology, there has been no category capturing this technology. A broader category, notably Biotechnology was identified as the closest corresponding technology and the related list of firms was downloaded and cleaned in order to capture the advanced technology within the focus of the project.

The advanced technology categories are not exclusive and in certain cases they might overlap. This is due to the nature of technologies and firm behaviour. As an example, there are a lot of firms that focus on Robotics but develop AI algorithms at the same time or develop Robotics solutions with the help of AI. Another example is a firm that combines machine learning and IoT to make railway a Mobility choice by increasing capacity, reliability and cost-efficiency. This firm is categorised both under AI and IoT in our research. Advanced Manufacturing has been defined as a broad category as already mentioned above and for instance Robotics startups can be also behind these values. These overlaps reflect a natural co-evolution and interlinkages between technologies.

Based on the merged dataset, we constructed the following indicators:

- Number of firms developing specific advanced technologies (in this case the list of companies have been further cleaned to include only the technology producers/developers through a keyword search in the business descriptions)
- Total last-round VC investment in advanced technologies in euro
- Number of VC-backed, advanced technology startups established since 2009 (following Dalle et al. we performed a similar search limited only to the sample of young companies less than 10 years old)

All financial information in Crunchbase expressed in US dollars was transformed in euro using the exchange rate provided by European Central Bank. If any financial information was not available in one data source, it was substituted by the other where available. Furthermore, all extreme values of 1% for the total funding amount and last funding amount were checked and removed when referring to errors.

9.1 Capturing market valuation of tech firms via Crunchbase and Dealroom

Entrepreneurship is a key element of advancing technological transformation in our industries. Capturing entrepreneurial dynamics is however not straightforward in particular when zooming into specific advanced technologies such as Artificial Intelligence or the Internet of Things. Entrepreneurship is defined by the density of relationships, the propensity to innovate, competitiveness and economic performance (Tsipouri et al., 2019). The pillars of entrepreneurial ecosystems can be captured through the following performance indicators:

- birth and death/survival rate of new businesses
- registration of new businesses
- jobs created by new businesses
- exports by new businesses
- investments (venture capital, private equity) secured by new businesses (Regh et al., 2018)

The 2017 of Startup Genome Report (Start up Genome, 2017) suggests the following metrics:

- Size (number of startups, valuation, thousand startups per million people)
- Experience (exits, unicorns)
- Resources
- Attractiveness of sub-sectors
- Global Connectedness (inbound and Outbound)
- Global Market Reach

The Advanced Technologies for Industry project analysed the evolution of startups and scaleups in various advanced technologies based on Crunchbase and Dealroom data and relying on simple metrics such as the count of startups and amount of VC and private equity investment. These metrics however often do not reflect the quality of the startups and their potential and leave out many of the factors mentioned above such as attractiveness, market reach or connectedness.

To fill this gap to some extent and to reflect about the quality of startups, we suggest to include a further indicator notably the valuation of the companies.

Valuation is "the analytical process of determining the current (or projected) worth of an asset or a company" (Investopedia). Valuation is determined by the quality of business management, the composition of its capital structure, the prospect of future earnings, or the market value of its assets.

Both Crunchbase and Dealroom includes data about valuations although only for a limited number of companies. For instance, in the case of Dealroom there is only 97 000 startups out of the 593 000 startups included in the database.

In addition to the actual valuation, Crunchbase also identifies a so-called Rank which is a dynamic ranking for all entities (in the Crunchbase dataset). It measures the prominence of an entity and takes many signals into account including the number of connections a profile has, the level of community engagement, funding events, news articles and acquisitions.

Based on these metrics, the indicator and underlying data can be collected on valuation for the EU27 and also capturing country differences within the EU.

Valuing a private company requires insight into the flow of capital across the entire venture capital, private equity and M&A landscape. The process is time-consuming and data dependent.

There are several methods for valuing a business. Each method has its pros and cons and can be used in different circumstances. Here is a quick look at two relevant valuation methods:

Method I: Comparable Valuation of Firms

The most common way to estimate the value of a private company is to use comparable company analysis (CCA) (Investopedia). This approach involves searching for publicly traded companies that most closely resemble the private or target firm.

The process includes researching companies of the same industry, ideally a direct competitor, similar size, age and growth rate. Typically, several companies in the industry are identified as similar to the target firm. Once an industry group is established, averages of their valuations or multiples can be calculated to provide a sense of where the private company fits within its industry[8].

Limits:

You may not be able to find comparable sales.

[8] Bhojraj, S., & Lee, C. M. (2002). Who is my peer? A valuation-based approach to the selection of comparable firms. Journal of accounting research, 40(2), 407-439.

If the sale data is not recent, it may not reflect the current market value.

Figuring out how to adjust the formula to reflect key differences, such as one company having ageing equipment or better-trained staff, may be tricky.

Method II: Private Equity Valuation Metrics[9]

The EBIDTA (earnings before interest, taxes, depreciation, and amortisation) multiple can help in finding the target firm's enterprise value (EV)—which is why it is also called the enterprise value multiple. EBITDA has emerged as the most commonly accepted performance measure on which to base valuation (Investopedia). This provides a much more accurate valuation because it includes debt in its value calculation.

The enterprise multiple is calculated by dividing the enterprise value by the company's earnings before interest taxes, depreciation and amortisation (EBIDTA). The company's enterprise value is sum of its market capitalisation, value of debt, minority interest, preferred shares subtracted from its cash and cash equivalents.

If the target firm operates in an industry that has seen recent acquisitions, corporate mergers or IPOs, the financial information can be used from those transactions to calculate a valuation.

To conclude, both of the methods are clearly data driven. The specifics of the data required for such types of analysis is also very sensitive and not easily available.

The challenge of this task is to create an indicator for AI technology based on Crunchbase data source and capture the valuation of companies. Based on the literature review and desk research three solutions to estimate the valuation of a company were investigated:

Capturing the amount of valuations at IPO

The main drawback of this approach is the limited information on IPO[10] in Crunchbase. We have run a pilot test with German and French AI firms, no relevant information on IPO have been found.

Capturing the amount of valuations through the latest funding rounds *(approach used by Dealroom database)*

Dealroom valuation approach is based on available information through a (public) source, or it is a range of 4-6 times the latest funding rounds. Several data points (all available in Dealroom), some of which include web visits, app downloads, number of employees (and trend), number of open jobs (and trend), investments, investors, founding team (strong founder/exceptional founder) are considered as well in this approach.

Nevertheless, replicating this approach with the data from Crunchbase is more challenging. The main problem concerns the data availability for the 4-6 times the latest funding rounds. Crunchbase database provides information only for the total amount of VC fundings and the last VC funding amount, no in-between information regarding funding amounts is reported.

Capturing the valuation through Crunchbase ranking

The Crunchbase rank uses Crunchbase's intelligent algorithms to score and rank entities (e.g. Company, People, Investors) in order to see what matters most in real time. The algorithms take into account many different variables, ranging from Total Funding Amount, the entity's strength of relationships with other entities in the Crunchbase ecosystem, and how many times the entity has been viewed recently.

The Crunchbase rank shows where an entity falls in the Crunchbase platform relative to all other entities in that entity type. An entity with a Crunchbase Rank of 1 has the highest rank relative to all other entities of that type.

Note: A company's Rank is not permanent. While Rank shows context, Crunchbase Trend Score demonstrates activity. As a company moves up or down in Rank, its Trend Score is impacted. Trend Score measures the rate of a company's activity on a 20-point scale. Scores closer to +10 mean it is moving up in rank much faster compared to their peers. Scores closer to -10 means it is moving down.

The main disadvantage of this approach is that Crunchbase ranking does not picture fully the financial side of the valuation, but only part of it in combination with other less relevant information. We recommend using this approach in combination with other methodologies.

None of the aforementioned methods will fully cover the needs for the valuation of companies. For the purpose to provide a more robust approach, we recommend combining several approaches and databases in one, such as Method I: Comparable Valuation of Firms based on Dealroom sample.

[9] Bernstrom, S. (2014). Valuation: the market approach. John Wiley & Sons.
[10] Deloof, M., De Maeseneire, W., & Inghelbrecht, K. (2009). How do investment banks value initial public offerings (IPOs)?. Journal of Business Finance & Accounting, 36(1-2), 130-160.

For ease of interpretation, we suggest measuring the valuation of companies as a range between minimum and maximum valuation values.

In order to come up with a valuation indicator (value) per country we followed up the subsequent logic:

As the baseline, we will use the Dealroom database where European AI companies are defined. In most cases, the valuation values in Dealroom are presented as a range between min-max values. The companies with available information on valuation will be grouped according to a 0-10 scale.

Each group of companies will be closely evaluated based on their parameters, such as age, size (number of employees), total funding amount, last funding amount, number of patents/trademarks. We will indicate the range of values (min-max approach) for each parameter mentioned above and present this information in the form of a matrix. Please see an example of the matrix below (Table 20).

Following the logic of comparable company analysis (CCA), we will assign the ranges to the companies from the Crunchbase database based on the Dealroom defined matrix. To check the robustness of this approach we will merge AI companies with valuation values from Dealroom with companies from Crunchbase and manually check if originally estimated valuation values corresponds to the defined categories from the matrix.

Table 20: Valuation method

Ranking	Min valuation	Max valuation	Range of employees	Min total funding	Max total funding	Min/max last funding amount;patents/trademarks
0	20 000	100 000	1-10	10 000	100 000	…
1	40 000	350 000	2-50	50 000	350 000	…
2	…	…				…
…	…	…				…
…	…	…				…
10	1 m	50 m	11-1000	1 m	7 m	…

Source: authors

Section 10

10. Calculation of composite scores

10.1 Overall framework

Composite indicators have been constructed for each dimension of the conceptual framework presented in Section 4 for each EU Member State:

- Technology-specific:
  - Technology generation (new technologies and competitive innovation)
  - Technology uptake (application and diffusion)
- Enabling conditions:
  - Skills
  - Investment
  - Innovation
  - Entrepreneurship
  - Collaboration
  - Infrastructure

Sectoral composites have been constructed for technology generation and uptake and for the Digital Maturity Index (see below).

These indicators cover advanced technologies as defined in Section 3 and collect them into a single tool that measures and presents progress across production, technology adoption and enabling conditions. The merging of the previous KETs Observatory and Digital Transformation Monitor enables synergies in the data collection and overall scope of a harmonised coverage of all the observed technologies.

Each of the composites was built from data gathered through the indicator framework and as presented in Section 4. The analytical steps to construct the composites included the following:

- Data treatment: namely check for scale adjustments, outliers and missing data, directional adjustments;
- N–rmalisation: min - max from 0 to 1;
- Performance: interpretation of correlation matrix (check for very high correlations, negative correlations);
- Aggregation: The index by pillar has been calculated by aggre39ormalizedeighted normalised indicators that take values from 0 to 100. An exception is the dimension of 'Technology generation' and 'AT specialisation in patents' for which a 1/3 weight has been applied versus 2/3 for the 'AT share of patents' and 'number of AT firms'. The specialisation indicators calculated for countries with an extremely low number of patents can fluctuate significantly between periods distorting the ranking of countries.

10.2 Industry Digital Maturity Index - composite indicator

Key among the composite indicators is a measure of digital maturity by industry. European industries differ in their level of adoption of digital technologies and their ability to exploit critical innovation enabling factors such as skills, entrepreneurship and research investments. The Industry Digital Maturity Index combines data from the ATI survey (July 2019) with data from Eurostat and other public sources to measure the use of these factors and therefore evaluate the level of digital maturity by industry.

By digital maturity we mean the ability of enterprises to fully exploit digital innovation in their business processes through digital transformation and technology adoption. Digital transformation is understood as a continuous process by which enterprises adapt to or drive disruptive changes in their customers and markets (external ecosystem) by leveraging digital competencies to innovate new business models, products, and services that seamlessly blend digital and physical and business and customer experiences while improving operational efficiencies and organisational performance. Digital transformation is a function of the variety and number of technologies adopted, of their implementation to specific application or process areas (defined as use cases), their ability to generate substantial business impacts to achieve the organisation’s business goals (such as revenues or profit improvements or increased customer satisfaction). This transformation process requires also the availability of appropriate skills, access to investment and funding resources and vision as well as leadership capability by the organisation’s management. Some of these factors do not depend only on the individual organisation but on the external framework conditions. The Index is designed to take into account these factors and is aligned with the ATI conceptual framework model of technology innovation, particularly concerning the identification of key enabling conditions.

This Index is different from the DESI Integration of Digital Technology Index of the European Commission, which consists of two composite indicators measuring only the business uptake of digital technologies, business digitisation and e-commerce, sourced from the Eurostat ICT survey. DESI provides a comprehensive set of measures covering both society and the economy.

This Industry Digital Maturity Index, by contrast, is only focused on business indicators, is not calculated by country but by industry, and is focused on evaluating the evolution of digital transformation in the business environment.

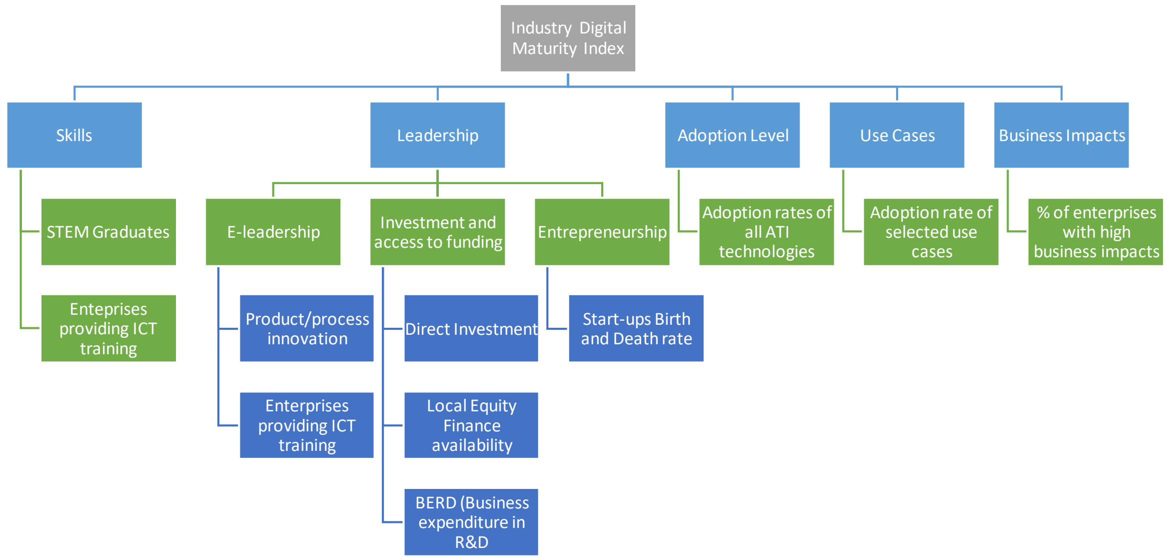
The Index is measured on a scale from 1 to 5, where 1 means very low digital maturity and 5 fully developed maturity. The Index results from the aggregation of 5 sub-indicators (Figure 6), normalised on the same scale, reflecting the mix of factors needed for successful technology innovation. Analysing the level of each of the sub-indicators by industry provides useful insights on the industries’ capabilities to achieve digital maturity and their relative strong and weak points.

Three of the sub-indicators are sourced from the ATI business survey (see chapter 6 for the survey methodology and results). Two of the sub-indicators are sourced from public sources.

The robustness of the Index is enhanced by the combination of public statistical sources such as Eurostat with survey data. The indicators sourced from the ATI survey are calculated by industry for the total EU, without breaking down the sample in sub-categories. This corresponds to high reliability and confidence levels.

The maturity model is a well-established business indicator with a well understood composition of key components: availability of skills, leadership (a composite measure including several sub-indicators of business dynamism and entrepreneurship), business impacts level, use cases and level of adoption of digital technologies. These maturity items have specific representative measures mapped to them where the measures fit appropriately. Figure 6 shows the pyramid of indicators which have been aggregated to measure each of the main components of the Index and then the Index itself. The main data sources are presented in Figure 6 below.

Figure 6: Structure and components of the Industry Digital Maturity Index



Source : authors

Skills

The availability of skills is a critical enabling factor for enterprises to adopt new technologies. In the Index this is measured through data about the supply of skills from higher education (the number of STEM graduates) and training (share of enterprises providing ICT training). The data is sourced from Eurostat.

Leadership

Vision and entrepreneurship are necessary for enterprises to become innovators and lead in digital transformation, even though they are difficult to measure. To understand industries capability in this dimension we combine several proxy indicators structured in 3 main sub-indicators :

E-Leadership is based on the following:

- share of enterprises developing innovative products,
- services or business models, sourced from Eurostat and
- share of enterprises providing ICT training.

Investment and access to funding, which combines the level of local equity finance availability, sourced from the World Economic Forum Competitiveness survey, the level of direct investment from the International Monetary Fund and the level of business expenditure for R&D (BERD) from Eurostat.

Entrepreneurship including the birth and death rates of startups, sourced from Eurostat.

Adoption level

This is a composite indicator of the level of digital technologies uptake, providing a good comparative measure of industries' technology innovation capability. The innovation process is boosted by the synergies between technologies, particularly digital technologies, so that a comprehensive measurement of technology adoption is particularly interesting.

Use case rates

This composite indicator measures the level of adoption of innovative use cases of digital technologies investigated in the survey, with higher ratings for the use cases focused on improving the customer experience or creating new products and services (rather than those focused on costs savings and process efficiency). This provides an additional measure of innovation capability by industry.

Business Impacts

This composite indicator measures the share of enterprises who achieved relevant business benefits (over 10% improvement) thanks to the adoption of advanced technologies. This was investigated in the survey for 7 business KPIs of high industrial relevance, including: revenues/profit increase, cost reduction, time efficiency, product/service quality improvement, number of new products or services launched, customer satisfaction, business model innovation. By combining the answers for all business impacts we enhance the reliability of the overall indicator. Even though the assessment of the business impacts is self-declared and not based on objective evidence, it reflects the enterprises' awareness of the relative success of their technology investments for their business. This provides the basis for a valuable comparative assessment of business impact by industry.

The final selection of indicators for the maturity model was normalised to a standard range and mapped to a five-point scale. These ratings were weighted appropriately to focus on those items that contribute most to maturity, and the evaluations and weights are multiplied to give a final measure of maturity.

Table 21: Industry Digital Maturity Index: Data sources by component

Index Component	Sub-Indicator	Weight	Measure	Data Source
Skills		50%	Share of Stem Graduates	Graduates in tertiary education - per 1000 of population aged 20-29 [educ_uoe_grad04] Mar-2019
Skills		50%	Enterprises providing ICT Training	Eurostat Enterprises that provided training to develop/upgrade ICT skills of their personnel [isoc_ske_ittn2] May 2019
Leadership	E-leadership	14%	Enterprises providing ICT Training	As above
Leadership	E-leadership	14%	Enterprises innovating products and services	Product and process innovative enterprises which introduced innovation by type of innovation, innovation developer [inn_cis10_prod] Jul 2019
Leadership	Investment and access to funding	14%	Direct Investment	Direct investment in the reportin– economy (flows) - annual data, – of GDP tipsbp90 - Apr 2019 IMF
Leadership	Investment and access to funding	14%	Local Equity Finance Availability	Average EU28-WE Forum - Global competitiveness Index Annual data, % of GDP
Leadership	Investment and access to funding	14%	Business expenditure in R&D (BERD)	Annual enterprise statistics by size class for special aggregates of activities [sbs_sc_sca_r2] Aug 2019 Business expenditure on R&D (BERD) by size class and source of funds [rd_e_berdsize] Jun 2019
Leadership	Entrepreneur ship	14%	Startups Birth Rate	Business demography by size class [bd_9bd_sz_cl_r2] Jul 2019
Leadership	Entrepreneur ship	14%	Startups Death Rate	Business demography by size class [bd_9bd_sz_cl_r2]

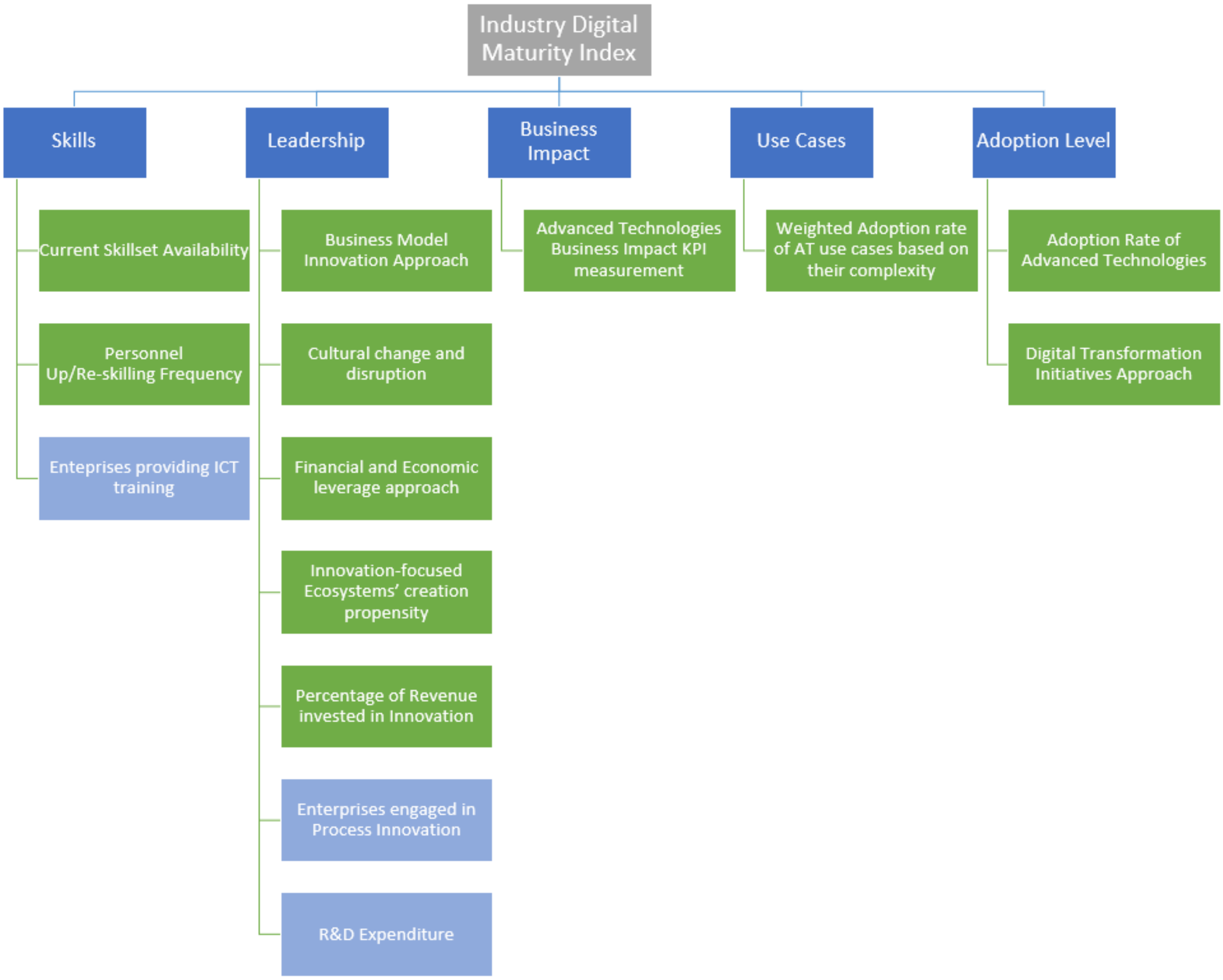
				Jul 2019
Adoption level		100%	Adoption rates	Composite from ATI survey
Use Cases		100%	Adoption rates of Use Cases	Composite from ATI survey (only digital technologies)
Business Impacts		14%	Business model innovation	Composite from ATI survey (only digital technologies)
		14%	Cost reduction	
		14%	Customer satisfaction	
		14%	Number of new products or services launched	
		14%	Product/service quality	
		14%	Revenue and/or profit growth	
		14%	Time efficiency	

Source : authors

10.3 Update of the Industry Digital Maturity Index (2021)

In the update of the General Findings report on on technology trends and technology adoption, considering the availability of new and additional ATI survey data and external indicators, the methodology of the Industry Digital Maturity Index was updated. See below the new structure of the components.

Figure 7: Structure and components of the Industry Digital Maturity Index



Source: IDC – Industry Digital Maturity Index (2021)
Note: Green Inputs are sourced from the latest ATI Survey (November 2020) – Light blue inputs are sourced from Eurostat

Skills

The availability of skills is a critical enabling factor for enterprises to adopt new technologies. In the Industry Digital Maturity Index, this is measured through data about the'current skillsets' (perceived) availability and the actions put in place to reskill and upskill personnel across organisations. The data is sourced from the 2021 ATI business survey and Eurostat.

Leadership

Vision and entrepreneurship are necessary for enterprises to become innovators and lead in digital transformation. A strong leadership, able to chart a solid and forward-looking digital road map and infuse a change-ready company mindset, is crucial for digital maturity. To und'rstand industries' capabilities in this dimension, we combine several ATI survey questions around: business-model innovation, cultural change and disruption, financial and economic leverage, propensity to create cross-organisation and cross-industry digital ecosystems, and proportion of innovation in organisational budgets. Eurostat indicators measuring the percentage of organisations engaged in process innovation initiatives and business expenditure on R&D have been considered as well. A weighted average of all these inputs determines an industry's 1-5 score for the leadership sub-indicator.

Business Impact

This composite indicator measures the proportion of enterprises that experienced relevant business benefits from the adoption of advanced technologies. This indicator was assessed in the survey by investigating the following seven highly industrially relevant KPIs: revenues/profit increase, cost reduction, time efficiency, product/service quality improvement, number of new products or services launched, customer satisfaction and business model innovation. By combining the answers for all business impacts, we enhance the reliability of the overall indicator. Even though the assessment of the business impacts is self-declared and not based on objective KPIs, it reflects enterprises' awareness of the relative success of their technology investments for their business. This provides the basis for a valuable comparative assessment of business impact by industry.

The final selection of indicators for the maturity model was normalised to a standard range and mapped to a five-point scale.

Use Cases

This composite indicator measures the level of adoption of use cases enabled by advanced technologies. A weighted scoring method provides higher ratings to more complex (e.g. difficult to implement from a technical point of view due to the need to integrate with legacy hardware/infrastructure) and forward-looking use cases that focus on improving the customer experience or creating new products and services (rather than those focused on costs savings and process efficiency).

Adoption Level

This is a composite indicator of the current level of uptake of advanced technologies and approaches to digital transformation initiatives, providing a comparative measure of industries' technology innovation capability.

Table 22: Industry Digital Maturity Index: Weights and Data sources by component

Index Component	Weight	Measure	Data Source
Skills	55%	Current Skillset Availability	ATI Survey (November 2020) – Question F2
	30%	Personnel Up/Re-skilling Frequency	ATI Survey (November 2020) – Question F3
	15%	Enterprises Providing ICT –raining	Eurostat - European Enterprises provided training to their personnel to develop their ICT skills (% - 2019)
Leadership	20%	Business Model Innovation Approach	ATI Survey (November 2020) – Question D2
	20%	Cultural Change and Disruption	ATI Survey (November 2020) – Question D3
	20%	Financial and Economic Leverage Approach	ATI Survey (November 2020) – Question D4
	7.5%	Innovation-Focused Ecosystems' Creation Propensity	ATI Survey (November 2020) – Question E3
	20%	Percentage of Revenue Invested in Innovation	ATI Survey (November 2020) – Question G1
	7.5%	Enterprises Engaged in Process In–ovation	Eurostat - European Enterprise engaged in Process Innovation (% - 2019)
	5%	R&D Exp–nditure	Eurostat - Business expenditure–on R&D (% of GDP - 2018)
Business Impact	14%	Business Model Innovation	Composite from ATI Surve– (November 2020) - Question E1
	14.3%	Cost Reduction	
	14.3%	Customer Satisfaction	
	14.3%	Number of New Products or Services Launched	
	14.3%	Product/Service Quality	
	14.3%	Revenue and/or Profit Growth	
	14.3%	Time Efficiency	
Use Cases	100%	Weighted Adoption Rate of AT Use Cases Based on Their Complexity	ATI Survey (November 2020) – Weighted Average of Questions C3-12 based on each technology current adoption – For that, a weighted (based on use case complexity) average of use cases adoption for each technology has been used
Adoption Level	60%	Adoption Rate of Advanced Technologies	ATI Survey (November 2020) – Question B1
	40%	Digital Transformation Initiatives Approach	ATI Survey (November 2020) – Question D1

Source: IDC – Industry Digital Maturity Index (2021)

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Appendix A: IPC codes

Technology	IPC codes
Advanced Manufacturing Technologies	B01D 15, B01D 67, B01J 10, B01J 12, B01J 13, B01J 14, B01J 15, B01J 16, B01J 19/02, B01J 19/08, B01J 19/18, B01J 19/20, B01J 19/22, B01J 19/24, B01J 19/26, B01J 19/28, B01J 20/30, B01J 21/20, B01J 23/90, B01J 23/92, B01J 23/94, B01J 23/96, B01J 25/04, B01J 27/28, B01J 27/30, B01J 27/32, B01J 29/90, B01J 31/40, B01J 38, B01J 39/26, B01J 41/20, B01J 47, B01J 49, B01J 8/06, B01J 8/14, B01J 8/24, B01J 10, B01L , B04B , B04C , B32B 37, B32B 38, B32B 39, B32B 41, B81C 3, B82B 3, B82Y 35, B82Y 40, C01B 17/20, C01B 17/62, C01B 17/80, C01B 17/96, C01B 21/28, C01B 21/32, C01B 21/48, C01B 25/232, C01B 31/24, C01B 9, C01C 1/28, C01D 1/28, C01D 3/14, C01D 5/16, C01D 7/22, C01D 9/16, C01F 1, C01G 1, C02F 11/02, C02F 11/04, C02F 3, C03B 20, C03B 5/24, C03B 5/173, C03B 5/237, C03B 5/02, C03C 21, , C03C 29, C04B 11/028, C04B 35/622, C04B 35/624, C04B 35/626, C04B 35/653, C04B 35/657, C04B 37, C04B 38/02, C04B 38/10, C04B 40, C04B 7/60, C04B 9/20, C07C 17/38, C07C 2/08, C07C 2/46, C07C 2/52, C07C 2/58, C07C 2/80, C07C 201/16, C07C 209/82, C07C 213/10, C07C 227/38, C07C 231/22, C07C 249/14, C07C 253/32, C07C 263/18, C07C 269/08, C07C 273/14, C07C 277/06, C07C 29/74, C07C 303/42, C07C 315/06, C07C 319/26, C07C 37/68, C07C 4/04, C07C 4/06, C07C 4/16, C07C 4/18, C07C 41/34, C07C 41/58, C07C 45/78, C07C 45/90, C07C 46/10, C07C 47/058, C07C 47/09, C07C 5/333, C07C 5/41, C07C 51/42, C07C 51/573, C07C 51/64, C07C 57/07, C07C 67/48, C07C 68/08, C07C 7, C07D 201/16, C07D 209/84, C07D 213/803, C07D 251/62, C07D 301/32, C07D 311/40, C07D 499/18, C07D 501/12, C07F 7/20, C07H 1/06, C07K 1, C08B 1/10, C08B 17, C08B 30/16, C08C , C08F 2/01, , C09B 41, C09B 67/54, C09D 7/14, C09J 5, C12M, C12S , C21C 5/52, C21C 5/54, C21C 5/56, C21C 7, C21D , C22B 11, C22B 21, C22B 26, C22B 4, C22B 59, C22B 9, C22C 1, C22C 3, C22C 33, C22C 35, C22C 47, C22F , C23C 14/56, C23C 16/54, C25B 9, C25B 15/02, C25C , C25D 1, C30B 15/20, C30B 35, C40B 60, D01D 10, D01D 11, D01D 13, D01F 9/133, D01F 9/32, D06B 23/20, D21H 23/20, D21H 23/70, D21H 23/74, D21H 23/78, D21H 27/22, F24J 1, F25J 3, F25J 5, F27B 17, F27B 19, F27D 19, F27D 7/06, G01C 19/5628, G01C 19/5663, G01C 19/5769, G01C 25, G01R 3, G11B 7/22, H01L 21, H01L 31/18, H01L 35/34, H01L 39/24, H01L 41/22, H01L 43/12, H01L 51/40, H01L 51/48, H01L 51/56, H01S 3/08, H01S 3/09, H01S 5/04, H01S 5/06, H01S 5/10, H05B 33/10, H05K 13, H05K 3
Advanced materials	B32B 9, B32B 15, B32B 17, B32B 18, B32B 19, B32B 25, B32B 27, B82Y 30, C01B 31, C01D 15, C01D 17, C01F 13, C01F 15, C01F 17, C03C, C04B 35, C08F, C08J 5, C08L, C22C, C23C, D21H 17, G02B 1, H01B 3, H01F 1/0, H01F 1/12, H01F 1/34, H01F 1/42, H01F 1/44, H01L 51/30, H01L 51/46, H01L 51/54.
Artificial Intelligence	according to: Baruffaldi‟ S., et al. (2020), "Identifying and measuring developments in Artificial Intelligence: Making th” impossible possible", OECD Science, Technology and Industry Working Papers, No. 2020/05, OECD Publishing, Paris, https://doi.org/10.1787/5f65ff7e-en. complemented by‟OECD definition for "cognition and m”aning, understanding" G06F 17/20-17/28, G06K 9, G06T 7, G10L 13/027, G10L 15, G10L 17, G10L 25/63, G10L 25/66; G06F 15/18 to ascertain best coverage in early years cf. Inaba and Squicciarini (2017), http://dx.doi.org/10.1787/ab16c396-en
Big Data	G06F 17/30∗#, G06F 19/10∗#, G06Q 30/02∗#, G06F 17/50∗#, G06N∗#
Industrial biotechnology	C02F 3/34, C07C 29, C07D 475, C07K 2, C08B 3, C08B 7, C08H 1, C08L 89, C09D 11, C09D 189, C09J 189, C12M, C12P, C12Q, C12S, G01N 27/327 except for co-occurrence with A01, A61, C07K 14/435, C07K 14/47, C07K 14/705, C07K 16/18, C07K 16/28, C12N 15/09, C12N 15/11, C12N 15/12, C12N 5/10, C12P 21/08, C12Q 1/68, G01N 33/15, G01N 33/50, G01N 33/53, G01N 33/68, G01N 33/566, C12N 1/19, C12N 1/21, C12N 1/15, C12N 15/00, C12N 15/10, C12P 21/02.
Internet of Things (IOT)	A61B 1/00%, A61B 5/00%, A61B 5/02%, A61B 5/04%, A61B 5/05%, A61B 5/103, G01S 13/75%, G01V 3/17%, G01V 15/00%, G05D 1/03%, G06K 7/00%, G06K 7/08%, G06K 7/10%, G06K 19/00%, G06K 19/06%, G06K 19/07%, G06K 19/077, G08B 5/22%, G08B 6/00%, G08B 13/14%, G08B 13/24%, G08B 21/00%, G08B 25/10%, G08B 29/00%, G09F 3/00%, G09F 3/03%, H01Q 7/00%, H01Q 9/04%, H02J 17/00%, H04Q 5/22%, H04Q 7/00%, H04Q 9/00%, H04B 1/48%, H04B 1/59%, H04B 7/00%, H04B 7/08%, H04B 5/00%, G08C 17/% combined ’ith keywords:

	%rfid%', %radio%frequency%ident%, %rfid%, %radio%f'equency%ident% %nfc%', %near%field%communicat%, %nfc%, %near%field%communicat%
IT for Mobility	H04B 7/185, H04B 10/105, G01S, G01C 11, G01C 19, G01C 21, G08G, G06F 17/00, G06F 19/00
Micro- and Nanoelectronics	G01R 31/26, G01R 31/27 , G01R 31/28 , G01R 31/303 , G01R 31/304, G01R 31/317, G01R 31/327, G09G 3/14, G09G 3/32, H01F 1/40, H01F 10/193, H01G 9/028, H01G 9/032, H01H 47/32, H01H 57, H01S 5, H01L, H03B 5/32, H03C 3/22, H03F 3/04, H03F 3/06, H03F 3/08, H03F 3/10, H03F 3/12, H03F 3/14, H03F 3/16, H03F 3/183, H03F 3/21, H03F 3/343, H03F 3/387, H03F 3/55, H03K 17/72, H05K 1, B82Y 25 (certain overlap to Nanotechnology).
Nanotechnology	B82Y (previously Y01N), B81C, B82B
Photonics	F21K, F21V, F21Y, G01D 5/26, G01D 5/58, G01D 15/14, G01G 23/32, G01J, G01L 1/24, G01L 3/08, G01L 11/02, G01L 23/06, G01M 11, G01P 3/36, G01P 3/38, G01P 3/68, G01P 5/26, G01Q 20/02, G01Q 30/02, G01Q 60/06, G01Q 60/18, G01R 15/22, G01R 15/24, G01R 23/17, G01R 31/308, G01R 33/032, G01R 33/26, G01S 7/481, G01V 8, G02B 5, G02B 6 (excl. subclasses 1, 3, 6/36, 6/38, 6/40, 6/44, 6/46), G02B 13/14, G03B 42, G03G 21/08, G06E, G06F 3/042, G06K 9/58, G06K 9/74, G06N 3/067, G08B 13/186, G08C 19/36, G08C 23/04, G08C 23/06, G08G 1/04, G11B 7/12, G11B 7/125, , G11B 7/13, , G11B 7/135, G11B 11/03, G11B 11/12, G11B 11/18, G11C 11/42, G11C 13/04, G11C 19/30, H01J 3, H01J 5/16, H01J 29/46, H01J 29/82, H01J 29/89, H01J 31/50, H01J 37/04, H01J 37/05, H01J 49/04, H01J 49/06, H01L 31/052, H01L 31/055, H01L 31/10, H01L 33/06, H01L 33/08, H01L 33/10, H01L 33/18, H01L 51/50, H01L 51/52, H01S 3, H01S 5, H02N 6, H05B 33
Robotics	keyword: robot%
Security	G06F12/14, G06F21, G06K19, G09C, G11C8/20, H04K, H04L9, H04M1/66, H04M1/663, H04M1/665, H04M1/667, H04M1/67, H04M1/673, H04M1/675, H04M1/68, H04M1/70, H04M1/727, H04N7/167, H04N7/169, H04N7/171, H04W12

Appendix B: PRODCOM and TRADE codes

Technology generation and exploitation approach

Technology	PRODCOM codes
Artificial Intelligence	26201400, 26201500, 26201700, 26202100, 26202200, 26403300, 26406050, 26701300, 26801100, 26801300, 27901150, 27902080, 27904530, 28231000, 28232210
Big Data	26201500, 26202100, 26801100, 26801300, 27904530, 28231000
Internet of Things (IoT)	26121080, 26122000, 26123000, 26201400, 26201800, 26202200, 26203000, 26302320, 26302370, 26401100, 26512020, 26512050, 26512080, 26514400, 26516330, 26516370, 26516690, 26518100, 26801200, 26801300, 27201100, 27201200, 27311100, 27311200, 27902050, 27903330, 27903370, 27904530, 27907010, 27907030
Robotics	26112260, 26113003, 26115020, 26115050, 26121080, 26517015, 26517019, 26518550, 26601119, 26601170, 26801300, 27903181, 28221840, 28292240, 28993935, 28993945
IT for Security	26113027, 26113034, 26113054, 26113065, 26113067, 26113080, 26114090, 26122000, 26123000, 26202200, 26203000, 26305020, 26305080, 26514400, 26801100, 26801300, 27902050
IT for Mobility	26511120, 26511150, 26511180, 26511200, 26512020, 26512050, 26516430, 26518100, 26702250, 26801300, 27903330, 27907010, 27907030, 29102430, 29102450, 30201100
Advanced Manufacturing Technology	26514500, 26515135, 26515175, 26515235, 26515239, 26515271, 26515283, 26515330, 26515350, 26515381, 26516200, 26516330, 26516350, 26516500, 26516690, 27903154, 27903181, 28152475, 28296050, 28411110, 28411130, 28411150, 28411170, 28992040, 28411220, 28411240, 28411270, 28412123, 28412127, 28412129, 28412213, 28412217, 28412223, 28412225, 28412240, 28412300, 28412301, 28412302, 28412303, 28413120, 28413140, 28413220, 28413240, 28413310, 28992020, 28992040, 28992060, 28993935, 28993945
Advanced Materials	20135275, 20136270, 20136500, 20165670, 20165970, 20593000, 20595230, 20595300, 20595400, 20595640, 20595650, 20595740, 20595940, 20602150, 20602140, 20602200, 20602320, 20602340, 20602390, 20602400, 21202420, 21202430, 21202440, 22192019, 23121210, 23121230, 23121250, 23121270, 23441100, 23441210, 23441230, 23991400, 23991500, 24101290, 24422100, 24422450, 26114010, 26702153, 27202300, 27901390, 32502235, 32502253, 32502255, 32502259, 32502290, 32504153, 32504155, 32504159, 32504170, 32504290, 32505010, 32505020
Industrial Biotechnology	20143271, 20143473, 20143475, 20144290, 20146470, 20201100, 20201590, 20595957, 20595990, 21102010, 21102020, 21105100
Micro- and Nanoelectronics	26112120, 26112150, 26112180, 26112220, 26112240, 26112260, 26112280, 26113003, 26113006, 26113023, 26113027, 26113034, 26113054, 26113065, 26113067, 26113080, 26113091, 26113094
Nanotechnology	20302130, 20302150, 20302170, 26112220, 26112240, 26114070, 32505010
Photonics	26112220, 26112240, 26114070, 26202200, 26403400, 26512020, 26515330, 26515350, 26516470, 26516630, 26518100, 26601115, 26601130, 26601170, 26601300, 26701100, 26701250, 26701600, 26702153, 26702155, 26702170, 26702180, 26702230, 26702250, 26702270, 26702310, 26702330, 26702390, 26801200, 27311100, 27311200, 27402500, 27403300, 27403910, 27902050, 28411110, 32501335

Advanced technologies	Trade code
Artificial Intelligence	847010, 847149, 847150, 847170, 847321, 852329, 852351, 852359, 852380, 852841, 852851, 852861, 853180, 854320, 854370, 900711, 900719, 950410
Big Data	847010, 847150, 847170, 852329, 852359, 852380, 854320
Internet of Things (IoT)	844331, 847149, 850610, 850630, 850640, 850650, 850660, 850680, 850690, 851762, 851769, 851950, 852340, 852351, 852352, 852359, 852380, 852610, 852691, 852692, 852713, 852719, 852791, 852799,

	852990, 853010, 853080, 853090, 853120, 853400, 854320, 854390, 854470, 900110, 902810, 902830, 903040, 903180
Robotics	842489, 842890, 847950, 848640, 851580, 852380, 853400, 854231, 902219, 902290, 903210, 903290
IT for Security	852329, 852351, 852352, 852359, 852380, 853110, 853120, 854232, 854233, 854290, 903040
IT for Mobility	852380, 852610, 852691, 852990, 853010, 853080, 853090, 860110, 900580, 901410, 901420, 901480, 901580, 902910
Advanced Manufacturing Technology	845610, 845620, 845630, 845690, 845710, 845730, 845811, 845921, 845931, 845951, 845961, 846011, 846021, 846031, 846221, 846231, 846241, 847950, 848610, 848620, 848630, 848640, 851531, 902410, 902480, 902730, 902750, 902810, 902820, 903082, 903180, 903281
Advanced Materials	281810, 284210, 284610, 284690, 285200, 300510, 300590, 300670, 321590, 340700, 380110, 380120, 380130, 380190, 380210, 381220, 381230, 381800, 382430, 390950, 391400, 400520, 400591, 400599, 540310, 540331, 540332, 540333, 540339, 540500, 550200, 550410, 550490, 690911, 690912, 690919, 700711, 700719, 700721, 700729, 760310, 760320, 850519, 850730, 850740, 850780, 852210, 854590, 900140, 900150
Industrial Biotechnology	291521, 291811, 291812, 291813, 291814, 291815, 291816, 291818, 291819, 291829, 291830, 291891, 291899, 292221, 292229, 292231, 292239, 292241, 292242, 292243, 292244, 292249, 293621, 293622, 293623, 293624, 293625, 293626, 293627, 293628, 293629, 293690, 350790, 380891
Micro- and Nanoelectronics	854110, 854121, 854129, 854130, 854140, 854150, 854160, 854231, 854232, 854233, 854239
Nanotechnology	320710, 320720, 320730, 320740, 321590, 380110, 380120, 380130, 380190, 850730, 850740, 850780, 854590
Photonics	845610, 852340, 853120, 854140, 854190, 854470, 900110, 900120, 900190, 900211, 900219, 900220, 900290, 900510, 900580, 900610, 900630, 900661, 900669, 900720, 900810, 900830, 900840, 901010, 901050, 901060, 901110, 901120, 901310, 901320, 901380, 901820, 902221, 902229, 902730, 902750, 903141, 903149

Appendix C: Survey questionnaires

Survey I (2019)

PROJECT SPECIFICATIONS

Sampling unit: 900 = base survey
Respondent eligibility: Must have at least 10 employees
Quotas/caps:

- **Employee size:**
  1. 10–249 employees [Soft quotas]
  2. 250–499 employees [Soft quotas]
  3. 500–999 employees [Soft quotas]
  4. 1,000+ employees [Soft quotas]

Countries:

France, Germany, Italy, the Netherlands, Spain, the United Kingdom, Denmark, Sweden
Czech Republic, Hungary, Poland

Data collection method**:** CATI/phone

INTRODUCTION AND BACKGROUND INFORMATION

IDC is conducting a research study to understand European businesses' needs and/or expectations around advanced technologies. *This study is part of a European Commission project for the Executive Agency for Small and Medium-Sized Enterprises (EASME); its aim is to monitor digital transformation and key enabling technologies within the Member States. The research is conducted by a consortium of organisations including Capgemini, Fraunhofer, IDC, Idea Consulting, Technopolis Group and Nesta.*

We are looking to speak with people who are involved in, or influence or are highly knowledgeable about their organisation's approach to, and potential use of, advanced technologies. A deep technical understanding of the use or development of these technologies is not required.

The interview will last around 25–30 minutes.

By law, your identity and all your answers will remain strictly confidential and will not be passed on or disclosed to any third party. We will use them in aggregate form together with the opinions of hundreds of other company representatives all over **Europe.**

GENERAL INTERVIEWING AND PROGRAMMING NOTES

- The target person must be the company's decision maker responsible for the company's ICT and advanced technology use. No secretaries, assistants and the like are allowed. The DK rate will be tracked.
- Avoid "Don't knows" whenever possible but do not force respondents into guessing.
- Do not suggest or read so-called escape codes — "Refused" or "Don't know" options.
- When asking for actual numbers, if the respondent initially says, "Don't know", ask for an estimate before asking for ranges. Actual numbers, even if estimated, are preferred over ranges.
- Verbatim responses to "Other, specify" or open-ended questions should be included in the data.
- Use the questionnaire number as written here as the variable name (QA1b should have a variable name of qA1b).

- Use *exact* variable names and option codes wherever possible. If names or codes must be changed due to programming considerations, they should be changed back to match the questionnaire *exactly*.
- Multiple-response questions are indicated and should not be changed to dichotomous (yes/no) questions. Maintain the question form as written here in all cases.

Definitions

Cloud Computing

Public cloud services are available on public networks and open to a largely unrestricted universe of potential users. Public clouds are designed for a market, not a single enterprise. Public cloud has all or most of the following characteristics:

1. Shared, standard service. Built for a market (public), not a single customer.
2. Solution packaged. A "turnkey" offering; integrates required resources.
3. Self-service. Administration and provisioning; may require some "onboarding" support.
4. Elastic scaling. Dynamic and fine grained.
5. Usage-based pricing. Supported by service metering.
6. Accessible via the Internet. Ubiquitous (authorised) network access.
7. Standard UI technologies. Browsers, RIA clients and underlying technologies.
8. Published service interface/API. Web services and other common Internet APIs.

Big Data

Big Data is a term describing the continuous increase in data and the technologies needed to collect, store, manage and analyse it. It is a complex and multidimensional phenomenon, impacting people, processes and technology.

Enterprise Mobility

According to IDC's definition, the enterprise mobility market is made up of a conglomeration of mobile solutions and technologies, including hardware, software and services, empowering a borderless workforce to securely work anywhere, at any time and from any device. It does not include only the provision of smartphones or tablets to the workforce but also all the tools and applications for transforming key processes, from internal operations to operations with customers and suppliers, all the way from the shop floor to the top floor and from the back office to the end customers.

The Internet of Things (IoT)

An aggregation of endpoints that are uniquely identifiable and that communicate bidirectionally over a network using some form of automated connectivity. Objects become interconnected, make themselves recognisable and acquire intelligence in the sense that they can communicate information about themselves and access information that has been provided by another source.

Artificial Intelligence (AI)

AI is defined as systems that can learn, reason and self-correct. These systems hypothesise and formulate possible answers based on available evidence, can be trained through the ingestion of vast amounts of content, and can adapt and learn from their mistakes and failures with some degree of autonomy. Recommendations, predictions and advice based on this AI framework provide users with answers and assistance in a wide range of applications and use cases.

Robotics

Robotics is technology that encompasses the design, building, implementation and operation of robots. Robotics is often organised into three categories:

- Application specific. This includes robotics designed to conduct a specific task or series of tasks for commercial purposes. These robots may be stationary or mobile but are limited in function as defined by the intended application.

- Multipurpose. Multipurpose robots can perform a variety of functions and movements determined by a user that programmes the robot for tasks, movement, range and other functions, and that may change the effector based on the required task. These robots function autonomously within the parameters of their programming to conduct tasks for commercial applications and may be fixed, "moveable" or mobile.
- Cognitive. Cognitive robots are capable of decision making and reason, which enables them to function within a complex environment. These robots can learn and make decisions to support optimal function and performance and are designed for commercial applications.

Augmented/Virtual Reality (AR/VR)

Augmented reality devices look to overlay digital information or objects with a person's current view of reality. As such, the user can see his/her surroundings while also seeing the AR content — virtual reality devices place end users into a completely new reality, obscuring the view of their existing reality.

Blockchain

A digital, distributed ledger of transactions or records, in which the ledger stores the information or data and exists across multiple participants in a peer-to-peer network. Distributed ledger technology (DLT) enables new transactions to be added to an existing chain of transactions using a secure, digital or cryptographic signature. Blockchain protocols aggregate, validate and relay transactions within the blockchain network. New blocks of transactions can be added to existing blockchains and dispersed to other parts of the blockchain network. Blockchain technology enables the data to exist on a network of instances or "nodes", enabling copies of the ledger to exist rather than being managed in one centralised instance. Nodes within the network contain a complete copy of the entire ledger, making it available to those that can access the network. There is no single central repository that stores the ledger.

Digital Transformation (DX)

DX is the continuous process by which enterprises adapt to or drive disruptive changes in their customers and markets (external ecosystem) by leveraging digital competencies to innovate new business models, products and services that seamlessly blend digital and physical and business and customer experiences while improving operational efficiencies and organisational performance. Digital transformation also typically includes at least one of the following 3rd Platform technologies: cloud, business analytics, enterprise mobility or social. IDC also includes all innovation accelerators in digital transformation spending (IoT, next-generation security, robotics, cognitive computing and augmented/virtual reality).

Advanced Materials

Advanced materials lead both to new reduced cost substitutes to existing materials and to new higher added-value products and services. Advanced materials offer major improvements in a wide variety of fields, e.g., in aerospace, transport, building and healthcare. They facilitate recycling, lowering the carbon footprint and energy demand as well as limiting the need for raw materials that are scarce in Europe.

Nanotechnology

Nanotechnology is an umbrella term that covers the design, characterisation, production and application of structures, devices and systems by controlling shape and size at nanometre scale. Nanotechnology holds the promise of developing smart nano and micro devices and systems and radical breakthroughs in fields such as healthcare, energy, environment and manufacturing. It excludes micro- and nanoelectronics.

Micro- and Nanoelectronics

Micro- and nanoelectronics deal with semiconductor components and/or highly miniaturised electronic subsystems and their integration in larger products and systems. They include fabrication, design, packaging and test from nano-scale transistors to micro-scale systems integrating multiple functions on a chip.

Security

Security products are tools designed using a wide variety of technologies to enhance the security of an organisation's networking infrastructure — including computers, information systems, Internet communications, networks, transactions, personal devices, mainframe and the cloud — and help to provide advanced value-added services and capabilities.

Cybersecurity products are utilised to provide confidentiality, integrity, privacy and assurance. With security applications, organisations can provide security management, access control, authentication, malware protection, encryption, data loss prevention (DLP), intrusion detection and prevention (IDP), vulnerability assessment (VA) and perimeter defence, among other capabilities. All these tools are designed to enhance the security of an organisation's computing infrastructure and help to provide advanced value-added services and capabilities.

Connectivity

Connectivity refers to all those technologies and services that enable end users to connect to a communication network. It encompasses an increasing volume of data, wireless and wired protocols and standards, and combinations within a single use case or location.

It includes fixed voice and mobile voice telecom services to enable fixed or mobile voice communications, but also fixed data and mobile data services to have access and transfer data via a network. More recently, thanks to the rise of Internet of Things scenarios, connectivity technology boundaries have expanded beyond wired and cellular (e.g., 3G, 4G, 5G) services to low power wide area network (LPWAN), satellite and short-range wireless technologies (e.g., Bluetooth, ZigBee).

Industrial Biotechnology

Industrial biotechnology or white biotechnology is the application of biotechnology for the industrial processing and production of chemicals, materials and fuels. It includes the practice of using micro-organisms or components of micro-organisms like enzymes to generate industrially useful products in a more efficient way (e.g., less energy use or fewer by products), or generate substances and chemical building blocks with specific capabilities that conventional petrochemical processes cannot provide. There are many examples of such bio-based products already on the market. The most mature applications are related to enzymes used in the food, feed and detergents sectors. More recent applications include the production of biochemicals and biopolymers from agricultural or forest wastes.

Photonics

Photonics is a multidisciplinary domain dealing with light, encompassing its generation, detection and management. Among other things it provides the technological basis for the economic conversion of sunlight to electricity which is important to produce renewable energy, and a variety of electronic components and equipment such as photodiodes, LEDs and lasers.

B2B Industrial Digital Platforms

B2B industrial digital platforms can be defined as virtual environments facilitating the exchange and connection of data between different organisations through a shared reference architecture and common governance rules. By linking different actors that are interested in sharing information in the form of data, industrial data platforms constitute a composite business ecosystem combining players from disparate backgrounds, thus fostering the creation of new data-driven services and innovative business processes.

Eligibility

Functional Area

I'll begin by getting some background information.
[INT: PLEASE READ OUT THE NOTE BELOW]

We will use the term organisation to describe your company, bank, hospital, agency, practice or other, covering its overall activities, across all sites/branches located in [COUNTRY]. Please answer the following questions in relation to this definition of organisation, and just for the operations relative to [COUNTRY].

[ASK ALL]

S1. Are you one of the best-qualified people to answer questions about the overall ICT, digital and technology strategy and activities of your organisation in [COUNTRY]?

1. Yes
2. No [ASK FOR REFERRAL, THANK AND END INTERVIEW]

Multinational

S2. Is your organisation present exclusively in [COUNTRY]? —

[SINGLE SELECT]

1. Yes, we are exclusively present in [COUNTRY]
2. No, we are part of an international group present in multiple countries

[ASK IF S2=2]

S3. In which country is your organisation's headquarters located?

[INSERT LIST OF COUNTRIES]

Section A — Organisation

A1. In which country is your organisation located?

1. Czech Republic **[CEE]**
2. Denmark **[NORDICS]**
3. France
4. Germany
5. Hungary **[CEE]**
6. Italy
7. Netherlands
8. Poland **[CEE]**
9. Spain
10. Sweden **[NORDICS]**
11. United Kingdom
12. Other **[TERMINATE]**

A2. Which of the following best describes your position within your organisation?

1. CEO, managing director, owner
2. VP of IT, CIO/CTO, head of IT
3. IT director
4. IT manager
5. Head of information management
6. Head of analytics/analytics director
7. Head of insight/Insight director
8. CDO (chief data officer, chief digital officer)
9. Digital director or digital manager
10. VP engineering
11. Enterprise or solutions architect
12. Senior data engineer/senior developer
13. C-level/board-level executive with responsibility for IT or advanced technology
14. COO/head of operations
15. Other line-of-business management function or IT decision influencer; please specify ________
    [MANAGER-LEVEL OR HIGHER; DO NOT EXCEED 10% OF SAMPLE]

A3. Approximately how many people are currently employed (full-time or part-time) in your organisation in your country, including all branches, divisions and subsidiaries?

1. Fewer than 10 [TERMINATE]
2. 10 to 49
3. 50 to 249
4. 250 to 499
5. 500 to 999
6. 1,000 to 2,499
7. 2,500 to 4,999
8. 5,000 or more
9. Don't know **[TERMINATE]**

A4. Which of the following industries best describes your organisation's primary business? Please make sure you are referring to your company, not your specific role within the organisation.

1. Agriculture
2. Banking
3. Insurance
4. Business or professional services, excluding IT services
5. IT services
6. Healthcare
7. Process manufacturing
8. Discrete manufacturing
9. Retail trade
10. Wholesale trade
11. Telecommunications
12. Media
13. Transport and logistics
14. Utilities
15. Oil and gas
16. Government
17. Education
18. Other **[TERMINATE]**

[HARD/MIN QUOTAS BY GROUP: Agriculture (1), FSI (2-3), professional services including IT services (4-5), healthcare (6), process manufacturing (7), discrete manufacturing (8), retail and wholesale (9-10), telecom and media (11-12), transport and logistics (13), utilities and oil and gas (14-15), government and education (16-17)

Section B — Technology Use

Adoption

B. Which of the following technologies is your organisation using or planning to use?

[SINGLE SELECT]

1 = Already using
2 = Plan to start using in the next 12 months
3 = Evaluating, but no plans to adopt yet
4 = Not using and no plans
0 = Not aware of, or never heard of this technology
99 = Don't know

Technologies List

B1. Public cloud
B2. Big Data and analytics solutions
B3. Mobile solutions that allow access to a business process or IT system via Internet-enabled mobile devices such as smartphones or tablets
B4. Internet of Things (IoT) solutions
B5. Artificial intelligence (AI) systems
B6. Robotics
B7. Augmented and virtual reality (AR/VR)
B8. Blockchain
B9. Security technology solutions
B10. Nanomaterials — excluding micro- and nanoelectronics
B11. Advanced materials
B12. Micro and nanoelectronics — excluding nanomaterials
B13. Photonics
B14. Industrial biotechnology
B15. Standard connectivity — fixed or mobile voice or data
B16. Advanced connectivity — short-range wireless (e.g., ZigBee, 6LoPAN), satellite, LPWAN (e.g., NB-IoT, LTE-M, Sigfox, LoRA)
B17. B2B industrial digital platforms

Section C — Technology Use Cases

Big Data
[ASK IF B2 = 1,2]

C1. In which of the following areas does your organisation use or plan to use Big Data?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1 = Already using
2 = Plan to adopt in the next 12 months
0 = Not using and no plans
99 = Don't know

[ASK IF A4=1 (Agriculture)]

1. Monitoring and predicting natural events (e.g., weather)
2. Yield prediction
3. Advanced supply tracking
4. Demand analysis and forecast
5. Risk management
6. Equipment management optimisation

[ASK IF A4=2,3 (Finance)]

1. Fraud prevention and detection
2. Compliance management
3. Operational intelligence
4. Business intelligence
5. Portfolio and risk exposure assessment
6. Customer profiling, targeting and optimisation of offers for cross-selling influencer analysis
7. Dynamic and personalised pricing
8. Customer call centre efficiency
9. Product innovation, product development, product performance analysis
10. Sentiment analysis and brand reputation
11. Financial advisory, robo advisory, product recommendation and personalisation
12. Improve cybersecurity
13. Business process optimisation
14. Channel performance analytics
15. Underwriting and loss modelling **[ASK only if A4 = 3 insurance]**
16. Catastrophe modelling **[ASK only if A4 = 3 insurance]**
17. Predictive damage assessments or predicting situational outcomes **[ASK only if A4 = 3 insurance]**
18. Claims analytics **[ASK only if A4 = 3 insurance]**
19. Telematics and IoT data analytics **[ASK only if A4 = 3 insurance]**
20. Proactive risk management **[ASK only if A4 = 3 insurance]**

[ASK IF A4=4,5 (Professional services)]

1. Demand signalling
2. Social media presence to assess client's competitive positioning
3. Ad targeting, analysis, forecasting and optimisation
4. Customer profiling, targeting and optimisation of offers for cross-selling

5. Social media listening and sentiment analysis
6. Campaign management and loyalty programmes
7. Personalised pricing
8. Analytics for R&D projects
9. Workforce management analysis and improvement
10. Predictive maintenance
11. Cybersecurity and information management

[ASK IF A4=6 (Health)]

1. Illness/disease progression (e.g., causal factors of illness, identification of possible co-morbid conditions or patients at risk of medical complications)
2. Clinical decision support/evidence-based medicine
3. Population risk stratification
4. Integration of patient pathways
5. Patient engagement
6. Reporting on productivity and organisation efficiency (e.g., resources utilisation, patient length of stay, planning outpatients' visits, operating room planning)
7. Reporting on quality of care
8. Reduce financial fraud and abuse
9. Prevent and respond to cybersecurity threats
10. Driving innovation in medical research

[ASK IF A4=7,8 (Manufacturing)]

1. Support service innovation — new service delivery models
2. Support product innovation (3D search and part reuse, crowdsourcing, etc.)
3. Analysis of operations related data — e.g., manufacturing operations (quality, maintenance, fast manufacturing resource planning — MRP)
4. Analysis of machine or device data (e.g., equipment, products, RFID, buildings, other sensors)
5. Analysis of online customer behaviour related data (clickstream analysis, web logs, social networking data)
6. Warranty management and service execution
7. Factory data analysis for continuous improvement initiatives
8. Concurrent engineering and product life-cycle management
9. Analysis of supply chain data

[ASK IF A4=9, 10 (Wholesale, Retail)]

1. Store location (either physical or digital) **[ASK only if A4 = 9 Retail]**
2. Merchandise and assortment planning **[ASK only if A4 = 9 Retail]**
3. Define a better strategy around workforce management
4. Enable digital supply chain **[ASK only if A4 = 10, Wholesale]**
5. Increase the overall productivity and efficiency of DCs/warehouses
6. Optimise and contextualise price strategies and price management
7. Manage customer lifetime value to reduce churn rate **[ASK only if A4 = 9 Retail]**
8. Deliver customer experience personalisation at scale **[ASK only if A4 = 9 Retail]**
9. Cross-sell and upsell at point of sale **[ASK only if A4 = 9 Retail]**
10. Support customer data security and privacy for fraud prevention and detection
11. Omni-channel orchestration optimisation (inventory, order fulfilment)

12. Monetise data gathered from the omni-channel ecosystem
13. Voice/text/image enabled commerce and customer service
14. Omni-channel marketing and advertising optimisation

[ASK IF A4=11 (Telecom)]

1. Network analytic and optimisation
2. Network investment planning
3. Customer scoring and churn mitigation
4. Optimisation of offers to clients for cross-sell
5. Customer centre and call centre efficiency
6. Fraud prevention
7. Cybersecurity and information management
8. Location-based services using GPS data and geospatial analytics
9. Price optimisation

[ASK IF A4=12 (Media)]

1. Customer scoring
2. Fraud prevention
3. Churn prevention and customer retention
4. Intellectual property management in media and entertainment
5. Digital asset/content management
6. Audience analysis
7. Marketing optimisation
8. New product identification and development
9. Real-time statistics for sport events
10. Cybersecurity and information management

[ASK IF A4=13 (Transport)]

1. Logistics optimisation
2. Location-based analytics using GPS data
3. Customer profiling, targeting and optimisation of offers for cross-selling
4. Sentiment analysis and brand reputation
5. Predictive maintenance
6. Capacity and pricing optimisation
7. Fleet optimisation
8. Traffic management
9. Analysis of passenger flow and behaviour
10. Prevent and respond to public security threats
11. Cybersecurity and information management

[ASK IF A4=14 (Utilities)]

1. Customer behaviour and interaction analysis
2. Energy consumption analysis
3. Revenue assurance (including theft and fraud detection)
4. Maintenance optimisation (including predictive maintenance)
5. Field service optimisation
6. Sensor-based grid optimisation

7. Distribution load forecasting and scheduling
8. Demand response planning
9. Compliance checks and audits

[ASK IF A4=15 (Oil and Gas)]

1. Sensor-based pipeline optimisation
2. Maintenance management
3. Compliance checks and audits
4. Natural resource exploration
5. Seismic data processing
6. Drilling surveillance and optimisation
7. Disaster and outage management

[ASK IF A4=16 (Government)]

1. Determine optimal level/rate for tax and fees
2. Improve revenue collection through reduction of fraud and abuse
3. Reduce internal financial fraud and abuse
4. Prevent and respond to cyberthreats
5. Prevent and respond to natural disasters
6. Personalise citizen services
7. Increase efficiency of internal processes
8. Citizens' sentiment analysis
9. Optimising city operations — transport, time to respond, etc.
10. Reduce operating costs

[ASK IF A4=17 (Education)]

1. Student recruiting
2. Student performance, success and retention
3. Teacher/professor performance, success and retention
4. Campus operation (finance, HR, physical security, logistics, accommodation) optimisation
5. Personalisation of student curricula
6. Course planning and costing
7. Alumni affairs
8. Fighting plagiarism and intellectual property management

IoT Solutions
[ASK IF B4 = 1 or 2]

C2. How is IoT currently used (or planned to be used) by your organisation?

[READ ALL; SINGLE SELECT]

1. Mere data collection
2. Collection and analysis of data, but with no direct effects on business yet
3. Collection and analysis of data with a direct impact on the automation and operative enhancement of my business
4. IoT is leading to new business models and additional revenues (e.g., the creation of new value-added products and services, or data trading) as well as automating and enhancing my business

[ASK IF B4=1 or 2]

C3. In which of the following areas does your organisation use or plan to use IoT?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1 = Already using
2 = Plan to adopt in the next 12 months
0 = Not using and no plans
99 = Don't know

[ASK IF A4=1 (Agriculture)]

1. Monitoring of climate conditions
2. Greenhouse automation
3. Within-field management zoning
4. Precision crop management
5. Traceability for food and feed logistics
6. Animal tagging and tracking
7. Driverless tractors and autonomous machines
8. Predictive maintenance of productions assets
9. Automatic track and trace of materials, tools and products inside the organisation (inventory and warehouse)
10. Automatic track and trace of materials, tools and products outside the organisation (along the supply chain)
11. Remote building asset surveillance (e.g., preventing physical intrusion)
12. Sensor-based staff identification and location (e.g., access control or time reporting)
13. Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=2 (Banking)]

1. ATM remote tracking for antitampering
2. Sensors within credit/debit cards to improve customer experience
3. Bank digital signage (internet connected) or connected kiosks for marketing and in-branch customer experience
4. Geolocation-based coupon promotions to improve customer experience
5. Risk management (collateral management)
6. Customer-facing device applications (smartwatch, fitness band, etc.)
7. Remote building asset surveillance (e.g., preventing physical intrusion)
8. Sensor-based staff identification and location (e.g., access control or time reporting)
9. Smart lighting/HVAC/elevator for energy saving
10. Geolocation supported security (e.g., using RFID)

[ASK IF A4=3 (Insurance)]

1. Usage-based insurance (UBI) for connected cars
2. UBI for connected homes
3. UBI in health/life insurance that leverages wearable tech
4. Telematics-enabled insurance fraud management
5. Evidence-based loss prevention in personal lines auto/home insurance through remote tracking, monitoring and alerts (dashcams, video doorbells, etc.)
6. Evidence-based loss prevention in commercial insurance through asset/inventory tracking and alerts (dashcams in fleet operation, equipment sensors in factories, etc.)

7. Evidence-based loss prevention in workers' compensation insurance with wearable tech
8. Customer engagement through Amazon Alexa or Google Home
9. Parametric insurance (e.g., flight delay/crop insurance smart contracts triggered based on sensor data)
10. Sensor-based risk prevention and claims settlement
11. Sale of IoT data to generate new revenue streams (includes sale to other insurers or ecosystem partners)
12. Sensor-based staff identification and location (e.g., access control or time reporting)
13. Smart lighting/HVAC/elevator for energy saving
14. Remote building asset surveillance (e.g., preventing physical intrusion)

[ASK IF A4=4,5 (Professional Services)]

1. Remote asset maintenance
2. Logistics and fleet management
3. Sensor-based automation of field service technicians' operations
4. Remote workforce/field service technician monitoring
5. Remote building asset surveillance (e.g., preventing physical intrusion)
6. Sensor-based staff identification and location (e.g., access control or time reporting)
7. Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=6 (Health)]

1. Smart pharmacy management (supporting pharmacy workflow and medication dispensation — for example, sensors and devices applied to medication cabinets, pharmacy carousels, anaesthesia workstations)
2. Sensor-based patient identification and location (e.g., neonatal, mental)
3. Laboratory and diagnostics (sensors and devices transmitting via-network patient health information to clinical and administrative information systems)
4. Clinical care (sensors remotely tracking vital signs of patients, particularly in critical care/intensive care units)
5. Smart temperature tracking of medical equipment (e.g., laboratory samples)
6. Smart environment temperature tracking (e.g., rooms and departments)
7. Sensor-based ambulance services automation
8. Remote patient monitoring (sensors tracking vital signs of chronic disease patients outside hospital/care facility)
9. Patients' wayfinding assistance (within the hospital with context-based information)
10. Real-time location of assets
11. Real-time tracking of sterilisation processing workflows and instruments
12. Physical security (e.g., preventing physical intrusion)
13. Sensor-based staff identification and location (e.g., access control or time reporting)
14. Smart lighting/HVAC/elevator for energy saving
15. Smart drug delivery

[ASK IF A4=7, 8 (Manufacturing)]

1. Improve customer service, predictive maintenance and remote assistance on products
2. Sensor-based control and coordination of shop floor devices (robots, station, conveyor belt, etc.)
3. Predictive maintenance of productions assets

4. Automatic track and trace of materials, tools and products inside the organisation (inventory and warehouse)
5. Automatic track and trace of materials, tools and products outside the organisation (along the supply chain)
6. Fleet and transportation equipment management
7. Sensor-based automation of field service technician operations
8. Connected products/wearables to enable new consumer services and business models
9. Remote building asset surveillance (e.g., preventing physical intrusion)
10. Sensor-based staff identification and location (e.g., access control or time reporting)
11. Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=9,10 (Wholesale, Retail)]

1. Connected vending machines
2. Fleet and transportation management
3. In-store RFID item/product tracking for inventory visibility/optimisation
4. Proximity marketing and real-time location-based customer engagement/tracking
5. Centralised/remotely controlled electronic shelf labels
6. Sensor network based interactive digital signage
7. Smart fitting rooms
8. Supply chain track and tracing through RFID and sensor networks
9. Smart parking systems
10. Remote building asset surveillance (e.g., preventing physical intrusion or loss)
11. Sensor-based staff identification and location (e.g., access control or time reporting)
12. Smart lighting/HVAC/elevator for energy saving
13. Connected products/wearables to enable new consumer services and business models
14. Other IoT use cases (please specify)

[ASK IF A4=11 (Telecom)]

1. Sensor-based automation of field service technician operations
2. Inventory monitoring
3. Energy optimisation in networks (e.g., energy savings in base stations)
4. Remote network maintenance (e.g., fault detection)
5. In-store intelligence (e.g., stock and supply optimisation)
6. Remote building asset surveillance (e.g., preventing physical intrusion)
7. Sensor-based staff identification and location (e.g., access control or time reporting)
8. Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=12 (Media)]

1. Sensor-based production development and enhancement
2. Remote broadcasting network maintenance
3. Geolocation-based advertising for the audience
4. Remote building asset surveillance (e.g., preventing physical intrusion)
5. Sensor-based staff identification and location (e.g., access control or time reporting)
6. Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=13 (Transport)]

1. Quality of shipment conditions (e.g., monitoring of vibrations, strokes, container openings or cold chain maintenance for insurance purposes)

2. Item location (e.g., search of individual items in big surfaces like warehouses or harbours)
3. Fleet tracking for predicting arrival times/delays or for delivery time updates
4. Sensor-based asset and infrastructure maintenance
5. Digital signage (internet connected) for marketing in offices, stations, airports and bus stops
6. Internet-connected ticketing machines
7. Sensor-based passenger traffic flow analysis
8. Sensor-based safety and security monitoring
9. Automated refuelling operations
10. Remote building asset surveillance (e.g., preventing physical intrusion)
11. Sensor-based staff identification and location (e.g., access control or time reporting)
12. Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=14 (Utilities)]

1. Remote asset monitoring
2. Sensor-based asset diagnostics and maintenance
3. Real-time remote demand management
4. Remote metre management
5. Home energy management for household customers
6. Commercial and industrial building energy management
7. Electric vehicle charging station management
8. Weather sensors
9. Sensor-based quality control
10. Remote workforce/field service technician monitoring
11. Fleet and transportation equipment management
12. Remote building asset surveillance (e.g., preventing physical intrusion)
13. Sensor-based staff identification and location (e.g., access control or time reporting)
14. In-company smart lighting/HVAC/elevator for energy saving

[ASK IF A4=15 (Oil and Gas)]

1. Production management and control/sensors on production floor or pipelines
2. Sensor-based asset diagnostics and maintenance
3. Automatic track and trace of materials, tools and products outside the organisation (along the supply chain)
4. Remote workforce/field service technician monitoring
5. Fleet and transportation equipment management
6. Connected drilling and extraction operations
7. Remote building asset surveillance (e.g., preventing physical intrusion)
8. Sensor-based staff identification and location (e.g., access control or time reporting)
9. Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=16 (Government)]

1. Asset and infrastructure management (e.g., roads, bridges, parks, public buildings)
2. Public transportation automation (e.g., congestion charging, bus and other vehicle tracking)
3. Environmental monitoring (e.g., weather/pollution, water, nature reserves)
4. Vehicle sharing services
5. Smart sensor-based waste collection
6. Sensor-based intelligent street lighting
7. Smart parking systems
8. Public safety and security

9. Connected officer wearables
10. Remote building asset surveillance (e.g., preventing physical intrusion)
11. Sensor-based staff identification and location (e.g., access control or time reporting)
12. Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=17 (Education)]

1. Smart campus logistics/transportation/parking
2. Sensor-based student attendance monitoring
3. Remote asset surveillance (e.g., preventing physical intrusion)
4. Sensor-based staff identification and location (e.g., access control or time reporting)
5. Smart lighting/HVAC/elevator for energy saving

AI Systems

[ASK IF B5 = 1 or 2]

C4. In which of the following areas does your organisation use or plan to use artificial intelligence systems?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1 = Already using
2 = Plan to adopt in the next 12 months
0 = Not using and no plans
99 = Don't know

[ASK IF A4=1 (Agriculture)]

1. Crop and soil health monitoring
2. Automated irrigation systems
3. Animal diagnosis and treatment
4. Optimising animal feeding
5. Autonomous early warning system
6. Yield prediction
7. Intelligent greenhouse automation system
8. Regulatory/compliance intelligence
9. Next best action for supply chain, operations and maintenance

[ASK IF A4=2, 3 (Banking, Insurance)]

1. Robotic process automation
2. Governance, risk and compliance (e.g., fraud analysis and investigation, cybersecurity management/automated threat intelligence and prevention systems, compliance management)
3. Smart self-service and value-added services (e.g., robo advisor, personal financial management)
4. New digital channels (voice banking, webchat, chatbots, virtual assistant)
5. Attrition management (e.g., staff, customers)
6. Smart business intelligence (e.g., providing information to business decision makers in a natural way/digital assistant for enterprise knowledge workers)
7. Automated claims processing (insurance only)
8. Automated insurance underwriting (insurance only)
9. Voice to text transcription (e.g., MiFID II interaction tracking)
10. Automated investment decisions, algorithmic trading
11. Loan underwriting (banking only)

12. Text analysis (e.g., analysis/interpretation of contracts, legal documents)
13. Predictive tools (e.g., liquidity management, investment management, algorithmic trading)
14. Automated reconciliation (e.g., trades, payments, AR/AP) (banking only)
15. Recruitment intelligence
16. Accounts payable/accounts receivable automation
17. Procurement intelligence
18. IT automation

[ASK IF A4=4,5 (Professional Services)]

1. Automated threat intelligence and prevention systems
2. Intelligent assistants for internal decision support (providing information to business decision makers in a natural way)
3. Intelligent assistants for patient/customer interactions (including chatbots and speech recognition)
4. Regulatory/compliance intelligence
5. IT automation
6. Recruitment intelligence
7. Accounts payable/accounts receivable automation
8. Next best action for sales and marketing
9. Pricing/promotions optimisation

[ASK IF A4=6 (Health)]

1. Intelligent patient monitoring (real-time analysis of patient data)
2. Clinical decision support
3. Predictive workforce management
4. Assets and physical resources optimisation
5. Intelligent assistants for patient interaction
6. Automated threat intelligence and prevention systems
7. Regulatory/compliance intelligence
8. Robotic process automation (RPA)
9. Revenue/financial flows optimisation
10. Predictive maintenance of medical equipment
11. Natural language processing for medical records
12. Imaging analytics for diagnostic support and guided therapy
13. IT automation
14. Recruitment intelligence
15. Accounts payable/accounts receivable automation
16. Procurement intelligence

[ASK IF A4=7, 8 (Manufacturing)]

1. Intelligent assistants for internal decision support (providing information to business decision makers in a natural way)
2. Intelligent assistants for customer interactions (including chatbots and speech recognition)
3. AI-powered robotic process automation (RPA) software to support business applications
4. Automated threat intelligence and prevention systems
5. Pricing/promotions/reimbursement optimisation
6. Regulatory/compliance intelligence
7. IT automation

8. Recruitment intelligence
9. Accounts payable/accounts receivable automation
10. Procurement intelligence
11. Cognitive intelligence embedded in the final product
12. Next best action for supply chain, operations and maintenance
13. Next best action for sales and marketing

[ASK IF A4=9, 10 (Wholesale, Retail)]

1. Store location (either physical or digital)
2. Store checkout automation (e.g., Amazon Go) [ASK only if A4 = 9]
3. Merchandise and assortment planning [ASK only if A4 = 9]
4. Define a better strategy around workforce management
5. Enable digital supply chain [ASK only if A4 = 10]
6. Increase the overall productivity and efficiency of DCs/warehouses
7. Optimise and contextualise price strategies and price management
8. Manage customer lifetime value to reduce churn rate [ASK only if A4= 9]
9. Deliver customer experience personalisation at scale [ASK only if A4 = 9]
10. Cross-sell and upsell at point of sale [ASK only if A4 = 9]
11. Customer data consent management
12. Support customer data security and privacy for fraud prevention and detection
13. Omni-channel orchestration optimisation (inventory, order fulfilment)
14. Monetise data gathered from the omni-channel ecosystem
15. Voice/text/image enabled commerce and customer service
16. Omni-channel marketing and advertising optimisation
17. Collecting business insights for innovation

[ASK IF A4=11 (Telecom)]

1. Automated threat intelligence and prevention systems
2. Intelligent field service operations (e.g., image analysis in base stations)
3. AI-powered network management or planning
4. Automated customer service (including chatbots)
5. Regulatory/compliance intelligence
6. IT automation
7. Marketing and advertising optimisation
8. Pricing/promotions optimisation or recommendations
9. Data monetisation (generating new revenue streams from end-user behavioural data)
10. Fraud detection and analysis
11. Intelligent robotic process automation (RPA) to automate business processes
12. Recruitment intelligence
13. Accounts payable/accounts receivable automation
14. Procurement intelligence

[ASK IF A4=12, 13 (Media, Transport)]

1. Automated threat intelligence and prevention systems
2. Reduce financial fraud and abuse
3. Automated customer service (including chatbots)
4. Regulatory/compliance intelligence
5. IT automation

6. Recruitment intelligence
7. Accounts payable/accounts receivable automation
8. Procurement intelligence
9. Marketing and advertising optimisation
10. Pricing/promotions optimisation

[ASK IF A4=14, 15 (Utilities, Oil and Gas)]

1. Next best action for customer operations
2. Next best action for asset operations and maintenance
3. Automated customer service (including chatbots)
4. Next best action for sales
5. Regulatory/compliance intelligence
6. Automated threat intelligence and prevention systems
7. IT automation
8. Recruitment intelligence
9. Accounts payable/accounts receivable automation
10. Procurement intelligence

[ASK IF A4=16 (Government)]

1. Determine optimal level/rate for tax and fees
2. Improve revenue collection
3. Reduce financial fraud and abuse
4. Prevent and respond to cyberthreats
5. Real-time tracking and reporting of events or incidents
6. Determine optimal level for social benefit payments
7. Personalise citizen services (including chatbots, virtual assistants)
8. Increase efficiency of internal processes

[ASK IF A4=17 (Education)]

1. Student recruiting
2. Student performance, success and retention
3. Teacher/professor performance, success and retention
4. Campus operation (finance, HR, physical security, logistics, accommodation) optimisation
5. Personalisation of student curricula
6. Course planning and costing
7. Alumni affairs
8. Adaptive learning
9. Fighting plagiarism and intellectual property management

Robotics

[ASK IF B6 = 1 or 2]

C5. In which of the following areas does your organisation use or plan to use robotics?

[SELECT ALL THAT APPLY — SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1 = Already using
2 = Plan to adopt in the next 12 months
0 = Not using and no plans
99 = Don't know

[ASK IF A4=1 (Agriculture)]

1. Drones for crop monitoring and management (e.g., spraying)
2. Robots for autonomous precision seeding
3. Robots for fertilising and irrigation
4. Harvesting robots
5. Weeding robots
6. Robots for thinning and pruning
7. Robots for shepherding and herding
8. Robots for milking
9. Product quality test and inspection
10. Logistics and automated transportation (e.g., warehousing, transport and delivery)
11. Inventory management
12. Monitoring, security and surveillance

[ASK IF A4=2, 3 (Banking, Insurance)]

1. Customer assistance and branch automation
2. Monitoring, security and surveillance
3. Facility management (e.g., cleaning operations)
4. Internal delivery and logistics operations
5. Use of robots and drones for faster claims adjudication and settlement

[ASK IF A4=4, 5 (Professional Services)]

1. Customer assistance
2. Monitoring, security and surveillance
3. Asset inspection, maintenance and repair
4. Cleaning operations

[ASK IF A4=6 (Health)]

1. Surgery (robot assisted surgery)
2. Diagnosis
3. Emergency service
4. Logistics (transfer and deliver supplies, pharmaceuticals, patient food, trash, etc.)
5. Pharmacy (smart pharmaceutical dispensers)
6. Disinfectant robots (supplies/room sterilisation)
7. Rehabilitation/disability assistance
8. Patient assistance (in hospital and/or at home)
9. Cleaning (floor mopping)
10. Drones for lab results/medical product transportation

[ASK IF A4=7, 8 (Manufacturing)]

1. Factory operations (e.g., welding, painting, dispensing, assembly)
2. Product quality test and inspection
3. Warehouse (pick and pack)
4. Logistics and automated transportation (e.g., warehousing, transport and delivery)

5. Inventory management
6. Remote hazardous operations
7. Monitoring, security and surveillance
8. Machine tending

[ASK IF A4=9, 10 (Wholesale, Retail)]

1. Shelf/inventory auditing and analytics
2. Returns processing in warehouse
3. Shelf stocking
4. In-store product picking
5. Warehouse/distribution centre picking
6. Sidewalk robots
7. Autonomous street vehicles
8. Customer assistance
9. Delivery to customers

[ASK IF A4=11 (Telecom)]

1. Customer assistance
2. Monitoring, security and surveillance
3. Asset inspection, maintenance and repair
4. Asset cleaning
5. Remote hazardous operations

[ASK IF A4=12 (Media)]

1. Monitoring, security and surveillance
2. Asset inspection, maintenance and repair
3. Asset cleaning
4. Production automation and assistance

[ASK IF A4=13 (Transport)]

1. Passenger/customer assistance
2. Cargo test inspection and quality
3. Monitoring, security and surveillance
4. Vehicle and infrastructure inspection, maintenance and repair
5. Cleaning operations
6. Delivery robots
7. Autonomous vehicles

[ASK IF A4=14 (Utilities)]

1. Drones — transmission line cleaning and inspection
2. Drones — pollution monitoring and measurement
3. Drones — radiation monitoring and measurement
4. Drones — monitoring, security and surveillance
5. Robots — transmission line cleaning and inspection
6. Robots — pollution monitoring and measurement
7. Robots — radiation monitoring and measurement
8. Robots — monitoring, security and surveillance
9. Robots — infrastructure repair

[ASK IF A4=15 (Oil and Gas)]

1. Drones — asset inspection
2. Drones — pollution monitoring and measurement
3. Drones — radiation monitoring and measurement
4. Drones — monitoring, security and surveillance
5. Robots — drilling operations
6. Robots — subsea infrastructure inspection and maintenance (e.g., ROV, AUV)
7. Robots — petroleum refinery operations

[ASK IF A4=16 (Government)]

1. Citizen assistance
2. Remote hazardous operations (firefighting, border patrol, clearing bombs, combat soldiers)
3. Monitoring, security and surveillance
4. Asset inspection, maintenance and repair
5. Autonomous street vehicles
6. Garbage and recycling collection and sorting
7. Autonomous public transport modes

[ASK IF A4=17 (Education)]

1. Teacher/professor assistance
2. Monitoring, security and surveillance
3. Cleaning operations
4. In-campus autonomous vehicles

AR/VR
[ASK IF B7 = 1 or 2]

C6. In which of the following areas does your organisation use or plan to use augmented/virtual reality?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1 = Already using
2 = Plan to adopt in the next 12 months
0 = Not using and no plans
99 = Don't know

[ASK IF A4=1 (Agriculture)]

1. Simulated agriculture training
2. Field or cattle data visualisation
3. Inventory visualisation and management
4. Machine status and maintenance

[ASK IF A4=2 (Banking)]

1. Augmented/virtual customer data visualisation (e.g., portfolio simulation, asset return, risk management)
2. AR/VR trading
3. AR/VR-based customer experience
4. AR/VR-based business meeting and collaboration
5. Workforce training

[ASK IF A4=3 (Insurance)]

1. Insurance damage assessment/object evaluation in claims
2. Insurance risk advice
3. Insurance product advice
4. AR/VR-based customer experience
5. AR/VR-based business meeting and collaboration
6. Workforce training

[ASK IF A4=4,5 (Professional Services)]

1. Workforce training
2. Creating engaging customer experiences
3. Marketing and sales
4. AR/VR-based business meeting and collaboration
5. Provide support to field service technicians
6. Project or product simulation and testing
7. Machine status and maintenance
8. Virtual property tours
9. Site design and management

[ASK IF A4=6 (Health)]

1. Anatomy diagnostic
2. Workforce training
3. AR/VR assisted surgery
4. AR/VR-enabled therapy/physical rehabilitation
5. Emergency assistance
6. Patient data visualisation
7. Internal videography

[ASK IF A4=7,8 (Manufacturing)]

1. Product development (e.g., simulation)
2. Augmenting service delivery with additional information (e.g., service instructions)
3. Testing serviceability of new products already in the design/engineering phase
4. Workforce training
5. Create engaging customer experiences
6. Provide support to maintenance technicians
7. Provide support to workers on the shop floor
8. Marketing and sales

[ASK IF A4=9, 10 (Wholesale, Retail)]

1. AR/VR shopping
2. AR/VR customer journey gamification
3. 3D environment preview
4. Inventory management
5. Workforce training

[ASK IF A4=11 (Telecom)]

1. Assessment of damage to assets
2. Support in asset repair tasks, including work order creation
3. On-field technician assistance
4. Simulation for support in new asset construction/build
5. Workforce training
6. AR/VR-based business meeting and collaboration

[ASK IF A4=12 (Media)]

1. AR/VR assisted production
2. AR/VR-based customer experience
3. Support in asset repair tasks, including work order creation
4. Workforce training
5. AR/VR-based business meeting and collaboration

[ASK IF A4=13 (Transport)]

1. Logistics/package delivery management
2. Passenger data visualisation DON'T ASK IF A2b = 43, 50 (logistics, postal and courier activities)
3. AR/VR assisted wayfinding within buildings (e.g., stations, airports)
4. AR/VR driving assistant
5. Vehicle status analysis and maintenance support
6. Workforce training

[ASK IF A4=14, 15 (Utilities, Oil and Gas)]

1. Visualisation of subsurface assets
2. Assessment of damage to assets
3. Support in asset repair tasks, including work order creation
4. Simulation for support in new asset construction/build
5. Training personnel on security procedures and safety
6. Training of new hires and reskilling of existing workforce

[ASK IF A4=16 (Government)]

1. Emergency response
2. Public infrastructure maintenance and damage assessment
3. Citizen services enhancement
4. Provide support to field service technicians
5. Workforce training

[ASK IF A4=17 (Education)]

1. AR/VR assisted lessons
2. Workforce training
3. Infrastructure maintenance and damage assessment

Blockchain

[ASK IF B8 = 1 or 2]

C7. In which of the following areas does your organisation use or plan to use blockchain?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1 = Already using
2 = Plan to adopt in the next 12 months
0 = Not using and no plans
99 = Don't know

[ASK IF A4= 1 (Agriculture)]

1. Food traceability
2. Supply chain transactions and payments
3. Smart logistics network
4. Regulatory compliance

[ASK IF A4= 2 (Banking)]

1. Cross-border payments and settlements
2. Custody and asset tracking
3. Identity management
4. Regulatory compliance
5. Trade finance and post-trade/transaction settlements
6. Transaction agreements

[ASK IF A4=3 (Insurance)]

1. Smart-contract-based parametric insurance (travel insurance, event insurance)
2. Blockchain platform for commercial insurance (e.g., collaborative model in complex marine insurance contracts)
3. Blockchain-based proof of insurance (certificate of insurance)
4. Secured cross-company data sharing (customer due diligence, financial and medical underwriting, risk assessment, fraud detection and regulatory compliance)
5. DLT-based claims settlement
6. Fraud handling
7. Regulatory compliance
8. Reinsurance contracts handling
9. Multinational smart-contract-based insurance policy

[ASK IF A4=4,5 (Professional Services)]

1. Land registry
2. Regulatory compliance
3. Identity management
4. Transaction agreements

[ASK IF A4=6 (Healthcare)]

1. Transaction agreements
2. Identity management
3. Clinic records management

[ASK IF A4=7, 8 (Manufacturing)]

1. Asset/goods management
2. Cross-border payments and settlements
3. Lot lineage/provenance
4. Regulatory compliance
5. Transaction agreements
6. Warranty claims

[ASK IF A4=9, 10 (Wholesale/Retail)]

1. Asset/goods management
2. Cross-border payments and settlements
3. Lot lineage/provenance
4. Regulatory compliance
5. Trade finance and post-trade/transaction settlements
6. Loyalty programmes
7. Warranty claims

[ASK IF A4=11 (Telecom)]

1. Payment transactions between carriers (e.g., wholesale or interconnect)
2. Regulatory compliance
3. Identity management
4. IoT management
5. Smart home/city management
6. Network/asset management

[ASK IF A4=12 (Media)]

1. Asset/goods management
2. Regulatory compliance
3. Identity management

[ASK IF A4=13 (Transport)]

1. Asset/goods management
2. Equipment and service/parts management
3. Loyalty programmes
4. Regulatory compliance
5. Trade finance and post-trade/transaction settlements

[ASK IF A4=14 (Utilities)]

1. Peer-to-peer wholesale energy trading
2. Peer-to-peer retail energy trading/microgrids
3. Metre-to-cash automation
4. Grid balancing, flexibility, ancillary services
5. Market data registry/exchange
6. eMobility services

[ASK IF A4=15 (Oil and Gas)]

1. B2B transactions
2. Commodity trade finance
3. Asset provenance/supply chain management
4. Resource tracking
5. JV accounting and notarisation

[ASK IF A4=16 (Government)]

1. Transaction agreements
2. Identity management
3. Tax collection
4. Payments
5. Case management
6. Voting
7. Asset registration

[ASK IF A4=17 (Education)]

1. Transaction agreements
2. Copyright and digital right protection
3. Student records and credentialing

Nanomaterials (excluding Micro and Nanoelectronics)
[ASK IF B10= 1 or 2]

C8. In which of the following areas does your organisation use or plan to use nano-technologies other than nanoelectronics?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1 = Already using
2 = Plan to adopt in the next 12 months
0 = Not using and no plans
99 = Don't know

1. Nanoparticles, nanowires and tubes
2. 2D nanomaterials
3. Nanostructured coatings
4. Nano emulsions and pigments

5. Nanomembranes
6. Nanomedicine

Advanced Materials
[ASK IF B11 = 1 or 2]

C9. In which of the following areas does your organisation use or plan to use advanced materials other than nanomaterials?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1 = Already using
2 = Plan to adopt in the next 12 months
0 = Not using and no plans
99 = Don't know

1. Advanced metals
2. Advanced synthetic polymers
3. Advanced ceramics
4. Novel composites
5. Advanced bio-based polymers
6. Electronic, magnetic and optical materials

Micro- and Nanoelectronics — Excluding Nanomaterials
[ASK IF B12= 1 or 2]

C10. In which of the following areas does your organisation use or plan to use micro and nanoelectronics?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1 = Already using
2 = Plan to adopt in the next 12 months
0 = Not using and no plans
99 = Don't know

1. Heterogeneous integration/embedded systems
2. Outside system connectivity (communication, data transfer, WiFi)
3. Heterogeneous components and "more than Moore" (MEMS, NEMS, sensors, transducers)
4. Optoelectronics (optical networks, optical sensors)
5. Analogue and mixed signal devices (µ-wave, RF, THz)
6. Power electronics
7. Computing (low-power computing, high-performance computing, new computing [non von Neumann, beyond CMOS, beyond Moore])
8. Memory and storage
9. Printed/flexible electronics
10. Equipment technology
11. Quantum technology

Photonics

[ASK IF B13= 1 or 2]

C11. In which of the following areas does your organisation use or plan to use photonics?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1 = Already using
2 = Plan to adopt in the next 12 months
0 = Not using and no plans
99 = Don't know

1. Intelligent/sensor-based equipment
2. Laser-based applications
3. Optical communication and networks
4. Lighting (LED, OLED)
5. Displays (LCD, plasma)
6. Optical fibres
7. Optical components and systems
8. Photodetectors (solar cells, photodiodes, phototransistors)

Industrial Biotechnology

[ASK IF B14= 1 or 2]

C12. In which of the following areas does your organisation use or plan to use industrial biotechnology?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1 = Already using
2 = Plan to adopt in the next 12 months
0 = Not using and no plans
99 = Don't know

1. Bio-based chemicals
2. Polymers, bioplastics
3. Biofuels
4. Antibiotics
5. Enzymes
6. Vitamins
7. Amino acids
8. High-value food and feed additives

Section D — Digital Transformation

D1. Please indicate which of the following best characterises your organisation's approach to digital transformation (DX).

[READ ALL, SELECT ONE] [INSERT DEFINITION OF DX]

1. Digital transformation initiatives are disconnected and poorly aligned with enterprise strategy and not focused on customer experiences.
2. Business has identified a need to develop digitally enhanced customer business strategies, but execution is on an isolated project basis.
3. Digital transformation goals are aligned at the enterprise level to near-term strategy and include digital customer product and experience initiatives.
4. Integrated, synergistic transformation management disciplines deliver digitally enabled, customer-centric products, services and experiences on a continuous basis.
5. Enterprise is aggressively disruptive in the use of new digital technologies and business models to affect markets and create new businesses.

D2. Which statement best describes your organisation's approach to business model innovation?

[READ ALL, SELECT ONE]

1. Leaders are unwilling to take serious risks based on adoption of digital opportunities.
2. Isolated functional attempts to innovate business models are limited by leadership resistance and an inability to exploit digital opportunities.
3. Leadership employs business model innovation to maintain competitive parity and product/service sustainability.
4. Leadership creates and uses new business models to influence customers and markets for competitive advantage.
5. Leadership is aggressively disruptive in the use of new digital technologies and business models to affect markets and create new businesses.

D3. Which statement best describes your organisation's approach to organisation and cultural change and disruption in relation to DX?

[READ ALL, SELECT ONE]

1. Reactive leadership culture drives organisational change only in response to competitive threats or performance deficiencies.
2. Risk-averse leadership governs an inflexible organisational structure that permits only a skunkworks approach to implementing digital initiatives.
3. Leadership fosters enterprise wide culture that quickly adopts governance and organisational changes in response to direction from leaders.
4. Leadership synchronises organisational and culture change to a continuously evolving leadership vision.
5. Organisational culture automatically adapts to the ecosystem as a result of embedded implicit understanding of leadership vision and governance.

D4. Which statement best describes your organisation's approach to financial and economic leverage?

[READ ALL, SELECT ONE]

1. Fixed budget cycles limit digital opportunities. Use of standard risk and return metrics inhibits the valuation of digital investments.
2. Funding for digital initiatives is allocated on a case-by-case basis. Valuation of risk and return are focused on specific localised business cases.
3. Enterprisewide digital strategies drive funding and valuation criteria. Metrics for success are linked to business outcome.

4. Valuation of enterprise digital products and services includes consideration of business ecosystem impact. Metrics span internal and external benefits.
5. Portfolio of digital investments includes strategic acquisitions and ecosystem relationships. Agile budgeting and metrics are synchronised with business model innovation.

Section E — Business

Business Alignment and KPIs

E1. In which of the following areas has your company implemented or plans to implement one or more of the advanced technologies?

[CHOOSE ALL THAT APPLY]

[RANDOMIZE, anchor #13&14]

1. Customer service and support
2. Engineering
3. Research and development (R&D)
4. Product innovation (new business initiatives)
5. Maintenance and logistics
6. Marketing
7. Finance
8. HR and legal
9. Sales
10. Product management
11. Governance, risk and compliance
12. IT and data operations
13. Other, please specify
14. All the above [exclusive choice]

E2. Which of the following *business goals* are driving adoption or consideration of the advanced technologies in your organisation?

[SELECT AT LEAST 3 AND UP TO 5 VERY IMPORTANT BUSINESS GOALS]

[RANDOMIZE, anchor #9]

1. Driving operational performance (EBITDA, revenues)
2. Attracting and retaining customers
3. Reducing operational and/or product costs, optimising business processes
4. Product, services or programme improvement and innovation
5. Expanding into new markets, segments or geographies
6. Managing regulatory compliance
7. Acquiring, integrating, spinning off business
8. Strengthening detection and resilience capabilities to guarantee security of people, facilities and resources
9. Improving detection and resilience capabilities against digital attacks
10. Empowerment, development and acquisition of talent
11. Improving reputation and brand awareness
12. Development of a broader, connected (partner) ecosystem
13. Commitment to sustainability and social welfare

E3. What's your approach to cooperating with other entities for innovation?

[SELECT ALL THAT APPLY]

1. We leverage mergers and acquisition to acquire innovations (patents, R&D capabilities)
2. We enter a number of partnerships with universities and/or research centres
3. We leverage partnerships with other companies working in the same industry
4. We leverage partnerships with other companies working in a different industry
5. We co-invent with the clients
6. We leverage an industry network where we share innovation resources and capabilities
7. We participate in EU/government-funded research projects
8. We do not have partnerships or collaborations of any type

[ASK IF B17=1,2]

9. **E4. What is the main benefit of participating in a B2B industrial digital platform?**
10. **[SINGLE SELECT]**
    11.
        1. Delivering new as-a-service offerings
        2. Secure data sharing
        3. Maintaining control over my data (data sovereignty)
        4. Accessing significantly larger markets
        5. Optimising use of underutilised assets — from data to property
        6. Increasing revenues
        7. Finding new partners

Benefits Realisation

E5. For the following business KPIs please indicate what percentage of improvement has been linked to the adoption of advanced technologies:

[SINGLE SELECT]

ANSWERS: Increase %: None (0%), Less than 5%, 5%–9%, 10%–24%, 25%–49%, 50% plus, don't know

1. Cost reduction
2. Revenue and/or profit growth
3. Time efficiency
4. Product/service quality
5. Customer satisfaction
6. Business model innovation
7. Number of new products or services launched

Section F — Advanced Technology Skills

F1. Which skills are most needed in the organisation to implement advanced technology-based products and projects?

[SELECT UP TO THREE]

1. General IT skills
2. Professional IT skills (e.g., programming)
3. Management skills
4. Customer handling skills
5. Problem solving skills
6. Foreign language skills
7. Technical, practical or job-specific skills
8. Numerical and data analytics skills

F2. For each selected skill, to what extent are the required skills available inside the organisation?

[SINGLE SELECT — for the skills selected in F1]

1. We don't have the skills at all yet
2. We have a significant shortfall
3. We have a small shortfall
4. We have all the skills we need

F3. For each selected skill, please estimate how difficult it will be in your company to acquire the required skills in the next two to three years.

[SINGLE SELECT — for the skills selected in F1]

1. Not at all difficult
2. Slightly difficult
3. Moderately difficult
4. Very difficult
5. Extremely difficult

Section G. Investment

G1. What percentage of your organisation's revenue is invested in IT and new technologies?

[SINGLE SELECT]

1. Less than 5%
2. 5%–9%
3. 10%–14%
4. 15% or more
5. Don't know

G2. Please indicate the share of your IT/technology budget invested in the following:

[PERCENTAGE — TOTAL MUST BE 100%]

1. R&D expenditure
2. Traditional IT spending
3. Advanced technologies (cloud, IoT, AI, AR/VR, blockchain, robotics, nanomaterials, photonics, industrial biotechnologies, etc.)
4. Industrial equipment and machinery

G3. From which source will your organisation get funds to invest in digital transformation and advanced technology adoption?

[CHOOSE ALL THAT APPLY]

1. Internal IT budget
2. Internal line-of-business budget
3. External investment through banks
4. External investment from venture capitalists
5. Government and EC investment in technology
6. Collaborative projects with organisations in the same value chain
7. Other, specify

Close

Thank you for your time and help today. Before I go, may I confirm that my name is {INTVRS->NAME} calling from………………………. All your replies will be treated in the strictest of confidence and in accordance with the Code of Conduct of the Market Research Society and ESOMAR. Should you require any further information, you may contact …………………………….
Alternatively, you may contact the Market Research Society on
|[SELECT BELOW]| or log onto our web site ……………………….

Thank you very much for your help. Have a good day.
Goodbye.

Survey II (2020)

PROJECT SPECIFICATIONS

Sampling unit: 900 = base survey

Respondent eligibility: Must have at least 10 employees

Quotas/caps:

- Employee size:
  - 10–249 Employees [Soft quotas]
  - 250–499 Employees [Soft quotas]
  - 500–999 Employees [Soft quotas]
  - 1 000+ Employees [Soft quotas]

Countries:
France, Germany, Italy, Netherlands, Spain, United Kingdom — 100 in each Western EU country
Denmark, Sweden — 100 in total for Nordics region
Czech Republic, Hungary, Poland — 200 in total for Central and Eastern EU region

Data collection method: CATI/phone

INTRODUCTION AND BACKGROUND INFORMATION

IDC is conducting a research study to understand European businesses' needs and/or expectations around advanced technologies. *This study is part of a European Commission project for the Executive Agency for Small and Medium-sized Enterprises (EASME); its aim is to monitor digital transformation and key enabling technologies within the Member States. The research is conducted by a consortium of organisations including Capgemini, Fraunhofer, IDC, Idea Consulting, Technopolis Group and Nesta.*

We are looking to speak with people who are involved, influence or are highly knowledgeable about their organisation's approach to, and potential use of, Advanced Technologies. A deep technical understanding of the use or development of these technologies is not required.

Our interview will last approximately 25-30 minutes.

By law, your identity and all your answers remain strictly confidential and will not be passed on or disclosed to any third party. We will use them in aggregate form together with the opinions of hundreds of other company representatives all over Europe.

GENERAL INTERVIEWING AND PROGRAMMING NOTES

- Target person must be company's decision-maker responsible for company's ICT and Advanced Technology use. No secretaries, assistants and the like allowed. DK-rate will be tracked.
- Avoid 'Don't knows' whenever possible but do not force respondents into guessing.
- Do not suggest or read so called escape codes - 'Refused' or 'Don't know' options.
- When asking for actual numbers, if respondent initially says, 'Don't know', ask for an estimate before asking for ranges. Actual numbers, even if estimated, are preferred over ranges.
- Verbatim responses to 'Other, specify', or open-ended questions should be included in the data.
- Use questionnaire number as written here as the variable name (QA1b should have a variable name of qA1b).
- Use exact variable names and option codes wherever possible. If names or codes must be changed due to programming considerations, they should be changed back to match the questionnaire exactly.
- Multiple-response questions are indicated and should not be changed to dichotomous (yes/no) questions. Maintain question form as written here in all cases.

DEFINITIONS

Cloud computing

Public cloud services are available on public networks and open to a largely unrestricted universe of potential users. Public clouds are designed for a market, not a single enterprise. Public cloud has all or most of the following characteristics:

Shared, standard service. Built for a market (public), not a single customer

Solution packaged. A 'turnkey' offering; integrates required resources

Self-service. Administration and provisioning; may require some onboarding support

Elastic scaling. Dynamic and fine grained

Usage-based pricing. Supported by service metering

Accessible via the Internet. Ubiquitous (authorised) network access

Standard UI technologies. Browsers, RIA clients and underlying technologies

Published service interface/API. Web services and other common Internet APIs

Big Data

Big Data is a term describing the continuous increase in data and the technologies needed to collect, store, manage and analyse it. It is a complex and multidimensional phenomenon, impacting people, processes and technology.

Enterprise Mobility

The enterprise Mobility market is made up of a conglomeration of mobile solutions and technologies, including hardware, software and services, empowering empowering a borderless workforce to securely work anywhere, at any time and from any device. It does not include only the provision of smartphones or tablets to the workforce but also all the tools and applications for transforming key processes, from internal operations to operations with customers and suppliers, all the way from the shop floor to the top floor and from the back office to the end customers.

The Internet of Things (IoT)

An aggregation of endpoints that are uniquely identifiable and that communicate bi-directionally over a network using some form of automated connectivity. Objects become interconnected, make themselves recognisable and acquire intelligence in the sense that they can communicate information about themselves and access information that has been provided by another source.

Artificial Intelligence (AI)

AI are defined as systems that learn, reason and self-correct. These systems hypothesise and formulate possible answers based on available evidence, can be trained through the ingestion of vast amounts of content and automatically adapt and learn from their mistakes and failures. Recommendations, predictions and advice based on this AI framework provide users with answers and assistance in a wide range of applications and use cases.

Robotics

Robotics is technology that encompasses the design, building, implementation and operation of robots. Robotics is often organised into three categories:

Application specific. This includes Robotics designed to conduct a specific task or series of tasks for commercial purposes. These robots may be stationary or mobile but are limited in function as defined by the intended application.

Multipurpose. Multipurpose robots are capable of performing a variety of functions and movements determined by a user that programs the robot for tasks, movement, range and other functions and that may change the effector based on the required task. These robots function autonomously within the parameters of their programming to conduct tasks for commercial applications and may be fixed, 'moveable' or mobile.

Cognitive. Cognitive robots are capable of decision making and reason, which allows them to function within a complex environment. These robots can learn and make decisions to support optimal function and performance and are designed for commercial applications.

Augmented/Virtual Reality (ARVR)

Augmented reality devices look to overlay digital information or objects with a person's current view of reality. As such, the user is able to see his/her surroundings while also seeing the AR content. Virtual reality devices place end users into a completely new reality, obscuring the view of their existing reality.

Blockchain

A digital, distributed ledger of transactions or records, in which the ledger stores the information or data and exists across multiple participants in a peer-to-peer network. Distributed ledgers technology (DLT) allows new transactions to be added to an existing chain of transactions using a secure, digital or cryptographic signature. Blockchain protocols aggregate, validate and relay transactions within the Blockchain network. New blocks of transactions can be added to existing Blockchains and dispersed to other parts of the Blockchain network. Blockchain technology allows the data to exist on a network of instances or 'nodes' allowing for copies of the ledger to exist rather than being managed in one centralised instance. Nodes within the network contain a complete copy of the entire ledger, making it available to those that can access the network. There is no single central repository that stores the ledger.

Digital transformation (DX)

Is the continuous process by which enterprises adapt to or drive disruptive changes in their customers and markets (external ecosystem) by leveraging digital competencies to innovate new business models, products,and services that seamlessly blend digital and physical and business and customer experiences while improving operational efficiencies and organisational performance. Digital transformation typically leverages at least one of the following technology pillars: cloud, business analytics, enterprise Mobility, or social. It also includes the so called innovation accelerators such as IoT, next-generation security, Robotics, Artificial Intelligence, Augmented/Virtual Reality, 3D printing, Blockchain.

Advanced Materials

Advanced Materials lead both to new reduced cost substitutes to existing materials and to new higher added-value products and services. Advanced Materials offer major improvements in a wide variety of different fields, e.g. in aerospace, transport, building and health care. They facilitate recycling, lowering the carbon footprint and energy demand as well as limiting the need for raw materials that are scarce in Europe.

Nanotechnology

Nanotechnology is an umbrella term that covers the design, characterisation, production and application of structures, devices and systems by controlling shape and size at nanometer scale. Nanotechnology holds the promise of leading to the development of smart nano and micro devices and systems and to radical breakthroughs in vital fields such as healthcare, energy, environment and manufacturing. It excludes Micro and Nanoelectronics.

Micro- and Nanoelectronics

Micro and nanoelectronics deal with semiconductor components and/or highly miniaturised electronic subsystems and their integration in larger products and systems. They include the fabrication, the design, the packaging and test from nano-scale transistors to micro-scale systems integrating multiple functions on a chip.

IT for Security

Security products are tools designed using a wide variety of technologies to enhance the security of an organisation's networking infrastructure — including computers, information systems, internet communications, networks, transactions, personal devices, mainframe and the cloud — as well as help provide advanced value-added services and capabilities.

Cybersecurity products are utilised to provide confidentiality, integrity, privacy and assurance. Through the use of security applications, organisations are able to provide security management, access control, authentication, malware protection, encryption, data loss prevention (DLP), intrusion detection and prevention (IDP), vulnerability assessment (VA) and perimeter defense, among other capabilities. All these tools are designed to enhance the security of an organisation's computing infrastructure as well as help provide advanced value-added services and capabilities.

It is possible to file patents for these applications and for the processes and based on this in conjunction with our empirical approach, we will be able to identify relevant sectors (NACE) or products (PRODCOM) and be able to estimate the share of 'security and connectivity' within these classes.

Connectivity

Connectivity refers to all those technologies and services that allow end-users to connect to a communication network. It encompasses an increasing volume of data, wireless and wired protocols and standards, and combinations within a single use case or location.

It includes Fixed Voice and Mobile Voice telecom services to allow fixed or mobile voice communications, but also Fixed Data and Mobile Data services to have access and transfer data via a network. More recently, also thanks to the rise of Internet of Things scenarios, connectivity technologies boundaries expand beyond wired and cellular (e.g. 3G, 4G, 5G) services to Low Power Wide Area Network (LPWAN), Satellite, and Short Range Wireless technologies (e.g. Bluetooth, zigbee).

Industrial Biotechnology

Industrial Biotechnology or white biotechnology is the application of biotechnology for the industrial processing and production of chemicals, materials and fuels. It includes the practice of using microorganisms or components of micro-organisms like enzymes to generate industrially useful products in a more efficient way (e.g. less energy use or less by-products), or generate substances and chemical building blocks with specific capabilities that conventional petrochemical processes cannot provide. There are many examples of such bio-based products already on the market. The most mature applications are related to enzymes used in the food, feed and detergents sectors. More recent applications include the production of biochemicals and biopolymers from agricultural or forest wastes.

Photonics

Photonics is a multidisciplinary domain dealing with light, encompassing its generation, detection and management. Among other things it provides the technological basis for the economic conversion of sunlight to electricity which is important for the production of renewable energy and a variety of electronic components and equipment such as photodiodes, LEDs and lasers.

ELIGIBILITY

Functional Area

I'll begin by getting some background information.

[INT: PLEASE READ OUT THE NOTE BELOW]

We will use the term organisation to describe your company, bank, hospital, agency, practice, or other, covering its overall activities, across all sites/branches located in [COUNTRY]. Please answer the following questions in relation to this definition of organization, and just for the operations relative to [COUNTRY].

[ASK ALL]

S1. Are you one of the best-qualified persons to answer questions about the overall ICT, digital, and technology strategy and activities of your organisation in [COUNTRY]?

Yes

No [ASK FOR REFERRAL, THANK AND END INTERVIEW]

Multi-national

S2. Is your organisation present exclusively in [COUNTRY]? -

[SINGLE SELECT]

Yes, we are exclusively present in [COUNTRY]

No, we are part of an international group present in multiple countries

[ASK IF S2=2]

S3. In which country is your organisation's headquarter located?

[INSERT LIST OF COUNTRIES]

SECTION A: ORGANISATION

A1. In which country is your organisation located?

Czech Republic [CEE]

Denmark [NORDICS]

France

Germany

Hungary [CEE]

Italy

Netherlands

Poland [CEE]

Spain

Sweden [NORDICS]

United Kingdom

Other [TERMINATE]

A2. Which of the following best describes your position within your organisation?

CEO, managing director, owner

VP of IT, CIO/CTO, head of IT

IT director

IT manager

Head of information management

Head of analytics /Analytics director

Head of insight / Insight Director

CDO (chief data officer, chief digital officer)

Digital Director or Digital Manager

VP engineering

Enterprise or solutions architect

Senior data engineer/senior developer

C-level/board-level executive with responsibility for IT or advanced technology

COO/head of operations

Other line-of-business management function or IT decision influencer; please specify _________ [MANAGER-LEVEL OR HIGHER; DO NOT EXCEED 10% OF SAMPLE]

A3. Approximately how many people are currently employed (full-time or part-time) in your organisation in your country, including all branches, divisions and subsidiaries?

Fewer than 10 [TERMINATE]

10 to 49

50 to 249

250 to 499

500 to 999

1 000 to 2 499

2 500 to 4 999

5 000 or more

Don't know [TERMINATE]

A4. Which of the following industries best describes your organisation's primary business? Please make sure you are referring to your company, not your specific role within the organisation.

Agriculture

Banking

Insurance

Business or professional services, excluding IT services

IT services

Healthcare

Process Manufacturing

Discrete Manufacturing

Retail trade

Wholesale trade

Telecommunications

Media

Transport and logistics

Utilities

Oil and Gas

Government

Education

Other [TERMINATE]

[HARD/MIN QUOTAS BY GROUP: Agriculture (1), financial services and insurance (2-3), professional services including IT services (4-5), healthcare (6), process manufacturing (7), discrete manufacturing (8), retail and wholesale (9-10), telecom and media (11-12), transport and logistics (13), utilities & oil and gas (14-15), government & education (16-17)

SECTION B: TECHNOLOGY USE

Adoption

B. Which of the following technologies is your organisation using or planning to use?

[SINGLE SELECT]

1= Already using

2 = Plan to start using in the next 12 months

3 = Evaluating, but no plans to adopt yet

4 = Not using and no plans

0 = Not aware of, or never heard of this technology

99 = Don't know

Technologies List

B1. Public Cloud

B2. Big Data and Analytics solutions

B3. Mobile solutions that allow access to a business process or IT system via Internet-enabled mobile devices such as smartphones or tablets

B4. Internet of Things (IoT) solutions

B5. Artificial Intelligence (AI) Systems

B6. Robotics

B7. Augmented and Virtual Reality (ARVR)

B8. Blockchain

B9. Security technology solutions

B10. Nanomaterials – excluding Micro and Nano Electronics

B11. Advanced Materials

B12. Micro and Nanoelectronics – excluding Nanomaterials

B13. Photonics

B14. Industrial Biotechnology

B15. Standard Connectivity - Fixed or Mobile voice or data

B16. Advanced Connectivity – Short range wireless (e.g. zigbee, 6LoPAN), Satellite, LPWAN (e.g. NB-IoT, LTE-M, Sigfox, LoRA)

SECTION C – TECHNOLOGY USE CASES

Big Data

[ASK IF B2 = 1,2]

C1. In which of the following areas does your organisation use or plan to use Big Data?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1= Already using

2 = Plan to adopt in the next 12 months

0 = Not using and no plans

99 = Don't know

[ASK IF A4=1 (Agriculture)]

Monitoring and predicting natural events (e.g. weather)

Yield prediction

Advanced supply tracking

Demand analysis and forecast

Risk management

Equipment management optimisation

[ASK IF A4=2,3 (Finance)]

Fraud prevention and detection

Compliance Management

Operational Intelligence

Business Intelligence

Portfolio and Risk exposure assessment

Customer profiling, targeting, and optimization of offers for cross-selling Influencer analysis

Dynamic and personalized pricing

Customer call center efficiency

Product innovation, product development, product performance analysis

Sentiment analysis and brand reputation

Financial advisory, robo advisory, product recommendation and personalization

Improve cyber security

Business process optimization

Channel performance analytics

Underwriting and loss modeling [ASK only if A4 = 3 insurance]

Catastrophe modeling [ASK only if A4 = 3 insurance]

Predictive damage assessments or predicting situational outcomes [ASK only if A4 = 3 insurance]

Claims analytics [ASK only if A4 = 3 insurance]

Telematics and IoT data analytics [ASK only if A4 = 3 insurance]

Proactive Risk Management [ASK only if A4 = 3 insurance]

[ASK IF A4=4,5 (Professional services)]

Demand signaling

Social media presence to assess client's competitive positioning

Ad targeting, analysis, forecasting and optimization

Customer profiling, targeting, and optimization of offers for cross-selling

Social media listening and sentiment analysis

Campaign management and loyalty programs

Personalized pricing

Analytics for R&D projects

Workforce management analysis and improvement

Predictive maintenance

Cyber security and Information Management

[ASK IF A4=6 (Health)]

Illness/ Disease Progression (e.g. causal factors of illness, identification of possible co-morbid conditions or identify patients at risk for medical complications)

Clinical Decision Support/ Evidence-based Medicine

Population risk stratification

Integration of patient pathways

Patient engagement

Reporting on productivity and organization efficiency (e.g. resources utilization, patient length of stay, planning outpatients' visits, operating rooms planning)

Reporting on quality of care

Reduce financial fraud and abuse

Prevent and respond to cybersecurity threats

Driving Innovation in Medical Research

[ASK IF A4=7,8 (Manufacturing)]

Support Service innovation - new service delivery models

Support product innovation (3D search and part reuse, crowdsourcing etc.)

Analysis of operations related data - e.g. manufacturing operations (Quality, maintenance, fast Manufacturing Resource Planning - MRP)

Analysis of machine or device data (e.g. equipment, products, RFID, buildings, other sensors)

Analysis of online customer behavior related data (clickstream analysis, web logs, social networking data)

Warranty management and service execution

Factory data analysis for continuous improvement initiatives

Concurrent engineering and product lifecycle management

Analysis of supply chain data

[ASK IF A4=9, 10 (Wholesale, Retail)]

Store location (either physical or digital) [ASK only if A4 = 9 Retail]

Merchandise and assortment planning [ASK only if A4 = 9 Retail]

Define a better strategy around workforce management

Enable digital supply chain [ASK only if A4 = 10, Wholesale]

Increase the overall productivity and efficiency of DCs/warehouses

Optimize and contextualize price strategies and price management

Manage customer lifetime value to reduce churn rate [ASK only if A4 = 9 Retail]

Deliver Customer Experience Personalization at scale [ASK only if A4 = 9 Retail]

Cross-sell and up-sell at point of sale [ASK only if A4 = 9 Retail]

Support customer data security and privacy for fraud prevention and detection

Omni-channel orchestration optimization (inventory, orders fulfillment)

Monetize data gathered from the omnichannel ecosystem

Voice/text/image enabled commerce and customer service

Omni-channel marketing and advertising optimization

[ASK IF A4=11 (Telecom)]

Network analytic and optimization

Network Investment Planning

Customer scoring and churn mitigation

Optimization of offers to clients for cross-sell

Customer center and call center efficiency

Fraud prevention

Cyber security and Information Management

Location based services using GPS data and geospatial analytics

Price optimization

[ASK IF A4=12 (Media)]

Customer scoring

Fraud prevention

Churn prevention and customer retention

Intellectual property management in media and entertainment

Digital asset/content management

Audience analysis

Marketing optimization

New product identification and development

Real-time statistics for sport events

Cyber security and Information Management

[ASK IF A4=13 (Transport)]

Logistics optimization

Location based analytics using GPS data

Customer profiling, targeting, and optimization of offers for cross-selling

Sentiment analysis and brand reputation

Predictive maintenance

Capacity and pricing optimization

Fleet Optimization

Traffic management

Analysis of passengers' flow and behavior

Prevent and respond to public security threats

Cyber security and Information Management

[ASK IF A4=14 (Utilities)]

Customer behavior and interaction analysis

Energy consumption analysis

Revenue Assurance (including Theft and Fraud Detection)

Maintenance optimization (including predictive maintenance)

Field service optimization

Sensor-based grid optimization

Distribution load forecasting and scheduling

Demand response planning

Compliance checks and audits

[ASK IF A4=15 (Oil and gas)]

Sensor-based pipeline optimization

Maintenance management

Compliance checks and audits

Natural resource exploration

Seismic data processing

Drilling surveillance & optimization

Disasters and outages management

[ASK IF A4=16 (Government)]

Determine optimal level/ rate for tax and fees

Improve revenue collection through reduction of fraud and abuse

Reduce internal financial fraud and abuse

Prevent and respond to cyberthreats

Prevent and respond to natural disaster

Personalize citizen services

Increase efficiency of internal processes

Citizens sentiment analysis

Optimizing city operations i.e. transport, time to respond, etc.

Reduce operating costs

[ASK IF A4=17 (Education)]

Student recruiting

Student performance, success and retention

Teacher/professor performance, success and retention

Campus operation (finance, HR, physical security, logistics, accommodation) optimization

Personalization of student curricula

Course planning and costing

Alumni affairs

Fighting plagiarism and intellectual property management

IoT solutions

[ASK IF B4 = 1 or 2]

C2. How is IoT currently used (or planned to be used) by your organisation?

[READ ALL; SINGLE SELECT]

Mere data collection

Collection and analysis of data, but with no direct effects on business yet

Collection and analysis of data with a direct impact on the automation and operative enhancement of my business

IoT is leading to new business models and additional revenues (e.g. the creation of new value-added products and services, or data trading) as well as automating and enhancing my business

[ASK IF B4=1 or 2]

C3. In which of the following areas does your organization use or plan to use IoT?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1= Already using

2 = Plan to adopt in the next 12 months

0 = Not using and no plans

99 = Don't know

[ASK IF A4=1 (Agriculture)]

Monitoring of climate conditions

Greenhouse automation

Within-field management zoning

Precision crop management

Traceability for food and feed logistics

Animals tagging & tracking

Driverless tractors & autonomous machines

Predictive maintenance of productions assets

Automatic track and trace of materials, tools and products inside the organization (inventory and warehouse)

Automatic track and trace of materials, tools and products outside the organization (along the supply chain)

Remote buildings asset surveillance (e.g. preventing physical intrusion)

Sensor-based staff identification and location (e.g., access control or time reporting)

Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=2 (Banking)]

ATMs' remote tracking for anti-tampering

Sensors within credit/debit cards for improving customer experience

Bank digital signage (internet connected) or connected kiosks for marketing and in-branch customer experience

Geolocation-based coupon promotions for improving customer experience

Risk management (collateral management)

Customer-facing device applications (smartwatch, fitness band etc.)

Remote buildings asset surveillance (e.g. preventing physical intrusion)

Sensor-based staff identification and location (e.g. access control or time reporting)

Smart lighting/HVAC/elevator for energy saving

Geolocation supported security (e.g. using RFID)

[ASK IF A4=3 (Insurance)]

Usage based insurance (UBI) for connected cars

UBI for connected homes

UBI in Health/Life Insurance that leverages wearable tech

Telematics enabled insurance fraud management

Evidence Based Loss Prevention in personal lines auto/home insurance through remote tracking, monitoring and alerts (e.g. dashcams, video door bells etc.)

Evidence Based Loss Prevention in Commercial Insurance through asset/inventory tracking and alerts (e.g. dashcams in fleet operation, equipment sensors in factories etc.)

Evidence Based Loss Prevention in Worker’s Compensation Insurance with wearable tech

Customer engagement through Amazon Alexa or Google Home

Parametric Insurance (e.g. flight delay/crop insurance smart contracts triggered based on sensor data)

Sensor-based risk prevention and claims settlement

Sale of IoT data to generate new revenue streams (includes sale to other insurers or ecosystem partners)

Sensor-based staff identification and location (e.g. access control or time reporting)

Smart lighting/HVAC/elevator for energy saving

Remote buildings asset surveillance (e.g. preventing physical intrusion)

[ASK IF A4=4,5 (Professional Services)]

Remote asset maintenance

Logistics and fleet management

Sensor-based automation of field service technicians' operations

Remote workforce/field service technicians monitoring

Remote buildings asset surveillance (e.g. preventing physical intrusion)

Sensor-based staff identification and location (e.g. access control or time reporting)

Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=6 (Health)]

Smart pharmacy management (supporting pharmacy workflow and medications dispensation - for example sensors and devices applied to medication cabinets, pharmacy carousels, anesthesia workstations)

Sensor-based patient identification and location (e.g. neonatal, mental)

Laboratory and diagnostics (sensors and devices transmitting via-network patient health information to clinical and administrative information systems)

Clinical care (sensors remotely tracking vital signs of patients, particularly in critical care/intensive care units)

Smart temperature tracking of medical equipment (e.g. laboratory samples)

Smart environment temperature tracking (e.g. rooms and departments)

Sensor-based ambulance services automation

Remote patient monitoring (sensors tracking vital signs of chronic disease patients outside hospital/care facility)

Patients wayfinding assistance (within the hospital with context-based information)

Real time location of assets

Real time tracking of sterilization processing workflows and instruments

Physical security (e.g. preventing physical intrusion)

Sensor-based staff identification and location (e.g. access control or time reporting)

Smart lighting/HVAC/elevator for energy saving

Smart drug delivery

[ASK IF A4=7, 8 (Manufacturing)]

Improve customer service, predictive maintenance and remote assistance on products

Sensor-based control and coordination of shop floor devices (robots, station, conveyor belt, etc.)

Predictive maintenance of productions assets

Automatic track and trace of materials, tools and products inside the organization (inventory and warehouse)

Automatic track and trace of materials, tools and products outside the organization (along the supply chain)

Fleet and transportation equipment management

Sensor-based automation of field service technicians' operations

Connected products/wearables to enable new consumer services and business models
Remote buildings asset surveillance (e.g. preventing physical intrusion)
Sensor-based staff identification and location (e.g., access control or time reporting)
Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=9,10 (Wholesale, Retail)]
Connected Vending Machines
Fleet and transportation management
In-store RFID items / products tracking for inventory visibility/optimization
Proximity marketing and real-time location-based customer engagement/tracking
Centralized / Remotely controlled Electronic Shelf Labels
Sensor network based interactive digital signage
Smart fitting rooms
Supply chain track and tracing through RFID and sensor networks
Smart parking systems
Remote buildings asset surveillance (e.g. preventing physical intrusion or loss)
Sensor-based staff identification and location (e.g. access control or time reporting)
Smart lighting/HVAC/elevator for energy saving
Connected products/wearables to enable new consumer services and business models
Other IoT use cases (please, specify)

[ASK IF A4=11 (Telecom)]
Sensor-based automation of field service technicians' operations
Inventory monitoring
Energy optimization in networks (e.g. energy savings in base stations)
Remote network maintenance (e.g. fault detection)
In-store intelligence (e.g stock and supply optimization)
Remote buildings asset surveillance (e.g. preventing physical intrusion)
Sensor-based staff identification and location (e.g access control or time reporting)
Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=12 (Media)]
Sensor-based production development and enhancement
Remote broadcasting network maintenance
Geolocation-based advertising for the audience
Remote buildings asset surveillance (e.g. preventing physical intrusion)
Sensor-based staff identification and location (e.g access control or time reporting)
Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=13 (Transport)]

Quality of shipment conditions (e.g. monitoring of vibrations, strokes, container openings or cold chain maintenance for insurance purposes)

Item location (e.g. search of individual items in big surfaces like warehouses or harbours)

Fleet tracking for predicting arrival times/delays or for delivery time updates

Sensor-based asset and infrastructure maintenance

Digital signage (internet connected) for marketing in offices, stations, airports, and bus stops.

Internet connected ticketing machines

Sensor-based passengers traffic flow analysis

Sensor-based safety and security monitoring

Automated refuelling operations

Remote buildings asset surveillance (e.g. preventing physical intrusion)

Sensor-based staff identification and location (e.g access control or time reporting)

Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=14 (Utilities)]

Remote asset monitoring

Sensor-based asset diagnostics and maintenance

Real-time remote demand management

Remote meter management

Home energy management for household customers

Commercial & industrial building energy management

Electric vehicles charging stations management

Weather sensors

Sensor-based quality control

Remote workforce/field service technicians monitoring

Fleet and transportation equipment management

Remote buildings asset surveillance (e.g. preventing physical intrusion)

Sensor-based staff identification and location (e.g access control or time reporting)

In-company smart lighting/HVAC/elevator for energy saving

[ASK IF A4=15 (Oil and Gas)]

Production management and control/sensors on production floor or pipelines

Sensor-based asset diagnostics and maintenance

Automatic track and trace of materials, tools and products outside the organization (along the supply chain)

Remote workforce/field service technicians monitoring

Fleet and transportation equipment management

Connected drilling and extraction operations

Remote buildings asset surveillance (e.g. preventing physical intrusion)

Sensor-based staff identification and location (e.g access control or time reporting)

Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=16 (Government)]

Asset and infrastructure management (e.g. roads, bridges, parks, public buildings)

Public transportation automation (e.g. congestion charging, bus and other vehicles tracking)

Environmental monitoring (e.g. weather/pollution, water, nature reserves)

Vehicle sharing services

Smart sensor-based waste collection

Sensor-based intelligent street lighting

Smart parking systems

Public safety and security

Connected officers' wearables

Remote buildings asset surveillance (e.g. preventing physical intrusion)

Sensor-based staff identification and location (e.g access control or time reporting)

Smart lighting/HVAC/elevator for energy saving

[ASK IF A4=17 (Education)]

Smart campus logistics/transportation/parking

Sensor-based student attendance monitoring

Remote asset surveillance (e.g. preventing physical intrusion)

Sensor-based staff identification and location (e.g., access control or time reporting)

Smart lighting/HVAC/elevator for energy saving

AI Systems

[ASK IF B5 = 1 or 2]

C4. In which of the following areas does your organisation use or plan to use Artificial Intelligence systems?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1= Already using

2 = Plan to adopt in the next 12 months

0 = Not using and no plans

99 = Don't know

[ASK IF A4=1 (Agriculture)]

Crop and soil health monitoring

Automated irrigation systems

Animals diagnosis and treatment

Optimizing animals feeding

Autonomous early warning system

Yield prediction

Intelligent greenhouse automation system

Regulatory / Compliance Intelligence

Next best action for supply chain, operations and maintenance

[ASK IF A4=2, 3 (Banking, Insurance)]

Robotic process automation

Governance, risk and compliance (e.g. Fraud Analysis and Investigation, Cyber security management / Automated threat intelligence and prevention systems, Compliance management)

Smart self-service and value-added services (e.g. robo advisor, personal financial management)

New digital channels (voice banking, webchat, chatbots, virtual assistant)

Attrition management (e.g. staff, customers)

Smart business intelligence (e.g. providing information to business decision makers in a natural way)/ Digital assistant for enterprise knowledge workers)

Automated Claims Processing (Insurance only)

Automated insurance underwriting (Insurance only)

Voice to text transcription (e.g. MiFID II interaction tracking)

Automated investment decisions, algorithmic trading

Loan underwriting (Banking only)

Text analysis (e.g. analysis/ interpretation of contracts, legal documents)

Predictive tools (e.g liquidity management, investment management, algorithmic trading)

Automated reconciliation (e.g. trades, payments, AR/AP) (Banking only)

Recruitment intelligence

Accounts payable / accounts receivable automation

Procurement intelligence

IT automation

[ASK IF A4=4,5 (Professional Services)]

Automated Threat Intelligence and Prevention Systems

Intelligent assistants for internal decision support (providing information to business decision makers in a natural way)

Intelligent assistants for patient/ customer interactions (including chatbots and speech recognition)

Regulatory / Compliance intelligence

IT automation

Recruitment intelligence

Accounts payable / accounts receivable automation

Next best action for sales and marketing

Pricing / promotions optimization

[ASK IF A4=6 (Health)]

Intelligent patient monitoring (real time analysis of patient data)

Clinical Decision Support

Predictive workforce management

Assets and physical resources optimization

Intelligent assistants for patient interaction

Automated Threat Intelligence and Prevention Systems

Regulatory / Compliance intelligence

Robotic process automation (RPA)

Revenue / financial flows optimization

Predictive maintenance of medical equipment

Natural language processing for medical records

Imaging analytics for diagnostic support and guided therapy

IT automation

Recruitment intelligence

Accounts payable / accounts receivable automation

Procurement intelligence

[ASK IF A4=7, 8 (Manufacturing)]

Intelligent assistants for internal decision support (providing information to business decision makers in a natural way)

Intelligent assistants for customer interactions (including chatbots and speech recognition)

AI-powered robotic process automation (RPA) software to support business applications

Automated Threat Intelligence and Prevention Systems

Pricing / promotions / reimbursement optimization

Regulatory / Compliance Intelligence

IT automation

Recruitment intelligence

Accounts payable / accounts receivable automation

Procurement intelligence

Cognitive intelligence embedded in the final product

Next best action for supply chain, operations and maintenance

Next best action for sales and marketing

[ASK IF A4=9, 10 (Wholesale, Retail)]

Store location (either physical or digital)

Store checkout automation (e.g. Amazon Go) **[ASK only if A4 = 9]**

Merchandise and assortment planning **[ASK only if A4 = 9]**

Define a better strategy around workforce management

Enable digital supply chain **[ASK only if A4 = 10]**

Increase the overall productivity and efficiency of DCs/warehouses

Optimize and contextualize price strategies and price management

Manage customer lifetime value to reduce churn rate **[ASK only if A4= 9]**

Deliver Customer Experience Personalization at scale **[ASK only if A4 = 9]**

Cross-sell and up-sell at point of sale **[ASK only if A4 = 9]**

Customer data consent management

Support customer data security and privacy for fraud prevention and detection

Omni-channel orchestration optimization (inventory, orders fulfillment)

Monetize data gathered from the omnichannel ecosystem

Voice/text/image enabled commerce and customer service

Omni-channel marketing and advertising optimization

Collecting business insights for innovation

[ASK IF A4=11 (Telecom)]

Automated Threat Intelligence and Prevention Systems

Intelligent field service operations (e.g. image analysis in base stations)

AI-powered network management or planning

Automated customer service (including chatbots)

Regulatory / Compliance intelligence

IT automation

Marketing and advertising optimization

Pricing / promotions optimization or recommendations

Data monetization (generating new revenue streams from end-user behavioural data)

Fraud detection and analysis

Intelligent robotic process automation (RPA) to automate business processes

Recruitment intelligence

Accounts payable / accounts receivable automation

Procurement intelligence

[ASK IF A4=12, 13 (Media, Transport)]

Automated Threat Intelligence and Prevention Systems

Reduce financial fraud and abuse

Automated customer service (including chatbots)

Regulatory / Compliance intelligence

IT automation

Recruitment intelligence

Accounts payable / accounts receivable automation

Procurement intelligence

Marketing and advertising optimization

Pricing / promotions optimization

[ASK IF A4=14, 15 (Utilities, Oil and Gas)]

"Next best action" for customer operations

"Next best action" for asset operations and maintenance

Automated customer service (including chatbots)

"Next best action" for sales

Regulatory / Compliance intelligence

Automated threat intelligence and prevention systems

IT automation

Recruitment intelligence

Accounts payable / accounts receivable automation

Procurement intelligence

[ASK IF A4=16 (Government)]

Determine optimal level / rate for tax and fees

Improve revenue collection

Reduce financial fraud and abuse

Prevent and respond to cyberthreats

Real time tracking and reporting of events or incidents

Determine optimal level for social benefit payments

Personalize citizen services (including chatbots, virtual assistants)

Increase efficiency of internal processes

[ASK IF A4=17 (Education)]

Student recruiting

Student performance, success and retention

Teacher / professor performance, success and retention

Campus Operation (finance, HR, physical security, logistics, accommodation) optimization

Personalization of student curricula

Course planning and costing

Alumni affairs

Adaptive learning

Fighting plagiarism and intellectual property management

Robotics

[ASK IF B6 = 1 or 2]

C5. In which of the following areas does your organization use or plan to use Robotics?

[SELECT ALL THAT APPLY – SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1= Already using

2 = Plan to adopt in the next 12 months

0 = Not using and no plans

99 = Don't know

[ASK IF A4=1 (Agriculture)]

Drones for crop monitoring and management (e.g. spraying)

Robots for autonomous precision seeding

Robots for fertilizing and irrigation

Harvesting robots

Weeding robots

Robots for thinning and pruning

Robots for shepherding and herding

Robots for milking

Product quality test and inspection

Logistics and automated transportation (e.g. warehousing, transport and delivery)

Inventory Management

Monitoring, security and surveillance

[ASK IF A4=2, 3 (Banking, Insurance)]

Customer assistance and branch automation

Monitoring, security and surveillance

Facility management (e.g. cleaning operations)

Internal delivery and logistics operations

Use of Robots and Drones for faster claims adjudication and settlement

[ASK IF A4=4, 5 (Professional Services)]

Customer assistance

Monitoring, security and surveillance

Asset inspection, maintenance, and repair

Cleaning operations

[ASK IF A4=6 (Health)]

Surgery (robot assisted surgery)

Diagnosis

Emergency Service

Logistic (transfer and deliver supplies, pharmaceuticals, patient food, trash…)

Pharmacy (smart pharmaceutical dispensers)

Disinfectant Robots (supplies/rooms sterilization)

Rehabilitation / disability assistance

Patient assistance (in hospital and/or at home)

Cleaning (floor mopping)

Drones for lab results/medical products transportation

[ASK IF A4=7, 8 (Manufacturing)]

Factory operations (e.g. welding, painting, dispensing, assembly)

Product quality test and inspection

Warehouse (pick and pack)

Logistics and automated transportation (e.g. warehousing, transport and delivery)

Inventory Management

Remote hazardous operations

Monitoring, security and surveillance

Machine tending

[ASK IF A4=9, 10 (Wholesale, Retail)]

Shelf/Inventory auditing & analytics

Returns processing in warehouse

Shelf stocking

In-store product picking

Warehouse / Distribution center picking

Sidewalk robots

Autonomous street vehicles

Customer assistance

Delivery to Customers

[**ASK IF A4=11 (Telecom)]**

Customer assistance

Monitoring, security and surveillance

Asset inspection, maintenance, and repair

Asset cleaning

Remote hazardous operations

[ASK IF A4=12 (Media)]

Monitoring, security and surveillance

Asset inspection, maintenance, and repair

Asset cleaning

Production automation and assistance

[ASK IF A4=13 (Transport)]

Passenger/Customer assistance

Cargo test inspection & quality

Monitoring, security and surveillance

Vehicle and infrastructure inspection, maintenance, and repair

Cleaning operations

Delivery robots

Autonomous vehicles

[ASK IF A4=14 (Utilities)]

Drones - Transmission line cleaning and inspection

Drones - Pollution monitoring and measurement

Drones -Radiation monitoring and measurement

Drones - Monitoring, security and surveillance

Robots – Transmission line cleaning and inspection

Robots - Pollution monitoring and measurement

Robots - Radiation monitoring and measurement

Robots - Monitoring, security and surveillance

Robots - Infrastructure repair

[ASK IF A4=15 (Oil and Gas)]

Drones - Asset inspection

Drones - Pollution monitoring and measurement

Drones -Radiation monitoring and measurement

Drones - Monitoring, security and surveillance

Robots - Drilling operations

Robots - Subsea infrastructure Inspection and Maintenance (e.g. ROV, AUV)

Robots - Petroleum Refinery Operations

[ASK IF A4=16 (Government)]

Citizen assistance

Remote hazardous operations (firefighting, border patrol, clearing bombs, combat soldiers)

Monitoring, security and surveillance

Asset inspection, maintenance, and repair

Autonomous street vehicles

Garbage and recycling collection and sorting

Autonomous public transport modes

[ASK IF A4=17 (Education)]

Teachers/professors assistance

Monitoring, security and surveillance

Cleaning operations

In-campus autonomous vehicles

AR/VR

[ASK IF B7 = 1 or 2]

C6. In which of the following areas does your organization use or plan to use Augmented/Virtual Reality?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1= Already using

2 = Plan to adopt in the next 12 months

0 = Not using and no plans

99 = Don't know

[ASK IF A4=1 (Agriculture)]

Simulated agriculture training

Field or Cattle data visualization

Inventory visualization and management

Machines status and maintenance

[ASK IF A4=2 (Banking)]

Augmented/Virtual customer data visualization (e.g. Portfolio simulation, asset return, risk management)

ARVR Trading

ARVR-based Customer Experience

ARVR-Based Business Meeting and Collaboration

Workforce Training

[ASK IF A4=3 (Insurance)]

Insurance damage assessment/object evaluation in claims

Insurance Risk Advice

Insurance Product Advice

ARVR-based Customer Experience

ARVR-Based Business Meeting and Collaboration

Workforce Training

[ASK IF A4=4,5 (Professional Services)]

Workforce Training

Creating engaging customer experiences

Marketing and sales

ARVR-Based Business Meeting and Collaboration

Provide support to field service technicians

Project or Product Simulation and Testing

Machines status and maintenance

Virtual property tours

Site design and management

[ASK IF A4=6 (Health)]

Anatomy diagnostic

Workforce Training

ARVR Assisted Surgery

ARVR enabled therapy/Physical rehabilitation

Emergency assistance

Patient data visualization

Internal videography

[ASK IF A4=7,8 (Manufacturing)]

Product development (e.g. simulation)

Augmenting service delivery with additional information (e.g. service instructions)

Testing serviceability of new products already in the design/engineering phase

Workforce Training

Create engaging customer experiences

Provide support to maintenance technicians

Provide support to workers on the shop floor

Marketing and sales

[ASK IF A4=9, 10 (Wholesale, Retail)]

ARVR shopping

ARVR customer journey gamification

3D environments preview

Inventory Management

Workforce Training

[ASK IF A4=11 (Telecom)]

Assessment of damage to assets

Support in asset repair tasks, including work order creation

On-field technicians assistance

Simulation for support in new asset construction/build

Workforce Training

ARVR Based Business Meeting and Collaboration

[ASK IF A4=12 (Media)]

ARVR Assisted Production

ARVR-based Customer Experience

Support in asset repair tasks, including work order creation

Workforce Training

ARVR-Based Business Meeting and Collaboration

[ASK IF A4=13 (Transport)]

Logistics/package delivery management

Passenger data visualization DON'T ASK IF A2b = 43, 50 (Logistics, Postal and courier activities)

ARVR Assisted Wayfinding within buildings (e.g. Stations, airports,..)

ARVR Driving Assistant

Vehicle status analysis and maintenance support

Workforce Training

[ASK IF A4=14, 15 (Utilities, Oil and Gas)]

Visualization of subsurface assets

Assessment of damage to assets

Support in asset repair tasks, including work order creation

Simulation for support in new asset construction/build

Training personnel on security procedures and safety

Training of new hires and reskilling of existing workforce

[ASK IF A4=16 (Government)]

Emergency response

Public Infrastructure Maintenance and Damage Assessment

Citizen Services Enhancement

Provide support to field service technicians

Workforce Training

[ASK IF A4=17 (Education)]

ARVR Assisted Lessons

Workforce Training

Infrastructure Maintenance and Damage Assessment

Blockchain

[ASK IF B8 = 1 or 2]

C7. In which of the following areas does your organization use or plan to use Blockchain?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1= Already using

2 = Plan to adopt in the next 12 months

0 = Not using and no plans

Don't know

[ASK IF A4= 1 (Agriculture)]

Food traceability

Supply chain transactions and payments

Smart logistics network

Regulatory compliance

[ASK IF A4= 2 (Banking)]

Cross-Border Payments & Settlements

Custody and Asset Tracking

Identity Management

Regulatory compliance

Trade Finance & Post Trade/Transaction Settlements

Transaction Agreements

[ASK IF A4=3 (Insurance)]

Smart contract based parametric insurance (travel insurance, event insurance)

Blockchain platform for commercial insurance (e.g. collaborative model in complex marine insurance contracts)

Blockchain based proof of insurance (certificate of insurance)

Secured cross-company data sharing (customer due diligence, financial and medical underwriting, risk assessment, fraud detection, and regulatory compliance)

DLT based claims settlement

Fraud handling

Regulatory Compliance

Reinsurance contracts handling

Multinational smart-contract-based insurance policy

[ASK IF A4=4,5 (Professional Services)]

Land Registry

Regulatory compliance

Identity Management

Transaction Agreements

[ASK IF A4=6 (Healthcare)]

Transaction Agreements

Identity Management

Clinic records management

[ASK IF A4=7, 8 (Manufacturing)]

Asset/Goods Management

Cross-Border Payments & Settlements

Lot Lineage/Provenance

Regulatory compliance

Transaction Agreements

Warranty claims

[ASK IF A4=9, 10 (Wholesale/Retail)]

Asset/Goods Management

Cross-Border Payments & Settlements

Lot Lineage/Provenance

Regulatory compliance

Trade Finance & Post Trade/Transaction Settlements

Loyalty programs

Warranty claims

[ASK IF A4=11 (Telecom)]

Payment transactions between carriers (e.g. wholesale or interconnect)

Regulatory compliance

Identity Management

IoT management

Smart home/city management

Network/asset management

[ASK IF A4=12 (Media)]

Asset/Goods Management

Regulatory compliance

Identity Management

[ASK IF A4=13 (Transport)]

Asset/Goods Management

Equipment and Service/Parts Management

Loyalty programs

Regulatory compliance

Trade Finance & Post Trade/Transaction Settlements

[ASK IF A4=14 (Utilities)]

Peer-to-peer wholesale energy trading,

Peer-to-peer retail energy trading/microgrids

Meter-to-cash automation,

Grid balancing, flexibility, ancillary services

Market data registry/exchange

E-Mobility services

[ASK IF A4=15 (Oil and Gas)]

B2B transactions

Commodity trade finance

Asset provenance/supply chain management

Resource tracking

JV accounting and notarization

[ASK IF A4=16 (Government)]

Transaction Agreements

Identity Management

Tax collection

Payments

Case Management

Voting

Asset Registration

[ASK IF A4=17 (Education)]

Transaction Agreements

Copyright and digital right protection

Student records and credentialing

Nanomaterials (excluding Micro and Nanoelectronics)

[ASK IF B10= 1 or 2]

C8. In which of the following areas does your organization use or plan to use Nano-Technologies other than nanoelectronics?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1= Already using

2 = Plan to adopt in the next 12 months

0 = Not using and no plans

99 = Don't know

Nanoparticles, Nanowires and tubes

2D nanomaterials

Nanostructured coatings

Nano emulsions and pigments

Nanomembranes

Nanomedicine

Advanced Materials

[ASK IF B11= 1 or 2]

C9. In which of the following areas does your organization use or plan to use Advanced Materials other than nanomaterials?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1= Already using

2 = Plan to adopt in the next 12 months

0 = Not using and no plans

99 = Don't know

Advanced metals

Advanced synthetic polymers

Advanced ceramics

Novel composites

Advanced biobased polymers

Electronic, magnetic and optical materials

Micro and Nanoelectronics – excluding Nanomaterials

[ASK IF B12= 1 or 2]

C10. In which of the following areas does your organization use or plan to use Micro and Nano Electronics?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1= Already using

2 = Plan to adopt in the next 12 months

0 = Not using and no plans

99 = Don't know

Heterogeneous integration/embedded systems

Outsides system connectivity (communication, data transfer, Wi-Fi)

Heterogeneous components & more than Moore (MEMS, NEMS, sensors, transducers)

Optoelectronics (optical networks, optical sensors)

Analogue and mixed signal devices (μ-wave, RF, THz)

Power electronics

Computing (low power computing, high performance computing, new computing (non von Neumann, beyond CMOS, beyond Moore))

Memory and storage

Printed/flexible electronics

Equipment technology

Quantum technology

Photonics

[ASK IF B13= 1 or 2]

C11. In which of the following areas does your organization use or plan to use Photonics?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1= Already using

2 = Plan to adopt in the next 12 months

0 = Not using and no plans

99 = Don't know

Intelligent/ sensor-based equipment

Laser based applications

Optical communication and networks

Lighting (LED, OLED)

Displays (LCD, plasma)

Optical fibres

Optical components & systems

Photodetectors (solar cells, photodiodes, phototransistors)

Industrial Biotechnology

[ASK IF B14= 1 or 2]

C12. In which of the following areas does your organization use or plan to use Industrial Biotechnology?

[SELECT "1 = Already using" or "2 = Plan to adopt in the next 12 months" for at least one solution]

1= Already using

2 = Plan to adopt in the next 12 months

0 = Not using and no plans

99 = Don't know

Bio based chemicals

Polymers, bioplastics

Biofuels

Antibiotics

Enzymes

Vitamins

Amino acids

High value food & feed additives

SECTION D: DIGITAL TRANSFORMATION

D1. Please indicate which of the following best characterises your organization's approach to Digital Transformation (DX).

[READ ALL, SELECT ONE] [INSERT DEFINITION OF DX]

Digital transformation initiatives are disconnected and poorly aligned with enterprise strategy and not focused on customer experiences.

Business has identified a need to develop digitally enhanced customer business strategies, but execution is on an isolated project basis.

5. Digital Transformation goals are aligned at the enterprise level to near-term strategy and include digital customer product and experience initiatives
6. Integrated, synergistic transformation management disciplines deliver digitally enabled, customer-centric products, services and experiences on a continuous basis
7. Enterprise is aggressively disruptive in the use of new digital technologies and business models to affect markets and create new businesses.

D2. Which statement best describes your organisation's approach to business model innovation?

[READ ALL, SELECT ONE]

8. Leaders are unwilling to take serious risks based on adoption of digital opportunities.
9. Isolated functional attempts to innovate business models are limited by leadership resistance and inability to exploit digital opportunities.
10. Leadership employs business model innovation to maintain competitive parity and product/service sustainability.
11. Leadership creates and uses new business models to influence customers and markets for competitive advantage.
12. Leadership is aggressively disruptive in the use of new digital technologies and business models to affect markets and create new businesses.

D3. Which statement best describes your organisation's approach to organization & cultural change and disruption in relation to DX?

[READ ALL, SELECT ONE]

13. Reactive leadership culture drives organizational change only in response to competitive threats or performance deficiencies
14. Risk-averse leadership governs an inflexible organizational structure that permits only skunkworks approach to implementing digital initiatives.
15. Leadership fosters enterprise wide culture that quickly adopts governance and organisational changes in response to direction from leaders.
16. Leadership synchronizes organizational and culture change to a continuously evolving leadership vision.
17. Organizational culture automatically adapts to ecosystem as a result of embedded implicit understanding of leadership vision and governance.

D4. Which statement best describes your organization's approach to financial and economic leverage?

[READ ALL, SELECT ONE]

18. Fixed budget cycles limit digital opportunities. Use of standard risk and return metrics inhibits the valuation of digital investments.
19. Funding for digital initiatives is allocated on a case-by-case basis. Valuation of risk and return are focused on specific localized business cases.
20. Enterprise wide digital strategies drive funding and valuation criteria. Metrics for success are linked to business outcome.
21. Valuation of enterprise digital products and services include consideration of business ecosystem impact. Metrics span internal and external benefits.

22. Portfolio of digital investments includes strategic acquisitions and ecosystem relationships. Agile budgeting and metrics are synchronized with business model innovation.

SECTION G: INVESTMENT

G1. What percent of your organisation's revenue is invested in IT and new technologies?

[SINGLE SELECT]

23. Less than 5 percent
24. 5-9 percent
25. 10-14 percent
26. 15 percent or more
27. Don't know

G2. Please indicate the share that your IT/Technology budget is invested in:

[PERCENTAGE – TOTAL MUST BE 100%]

28. R&D expenditure
29. Traditional IT spending
30. Advanced technologies (Cloud, IoT, AI, ARVR, Blockchain, Robotics, Nanomaterials, Photonics, Industrial Biotechnologies….)
31. Industrial equipment and machinery

G3. From which source will your organization get funds to invest in digital transformation and advanced technology adoption?

[CHOOSE ALL THAT APPLY]

32. Internal IT budget.
33. Internal Line of Business budget.
34. External investment through banks.
35. External investment from venture capitalists.
36. Government and EC investment in technology.
37. Collaborative projects with organizations in the same value chain.
38. Other, specify

SECTION E : BUSINESS

Business Alignment and KPIs

E1. In which of the following areas has your company implemented or plans to implement one or more of the advanced technologies?

[CHOOSE ALL THAT APPLY]

[RANDOMIZE, anchor #13&14]

39. Customer service and support
40. Engineering
41. Research and development (R&D)
42. Product innovation (new business initiatives)

43. Maintenance and logistics
44. Marketing
45. Finance
46. HR and legal
47. Sales
48. Product management
49. Governance, risk, and compliance
50. IT and data operations
51. Other, please specify
52. All the above [exclusive choice]

E2. Which of the following business goals are driving adoption or consideration of the advanced technologies in your organization?

[SELECT AT LEAST 3 AND UP TO 5 VERY IMPORTANT BUSINESS GOALS]

[RANDOMIZE, anchor #9]

53. Driving operational performance (EBITDA, revenues)
54. Attracting and retaining customers
55. Reducing operational and/or product costs, optimizing business processes
56. Product, services, or program improvement and innovation
57. Expanding into new markets, segments or geographies
58. Managing regulatory compliance
59. Acquiring, integrating, spinning off business
60. Strengthening detection and resilience capabilities to guarantee security of people, facilities and resources
61. Improving detection and resilience capabilities against digital attacks
62. Empowerment, development and acquisition of talent
63. Improving reputation and brand awareness
64. Development of a broader, connected (partner) ecosystem
65. Commitment to sustainability and social welfare

E3. What's your approach to cooperating with other entities for innovation?

[SELECT ALL THAT APPLY]

66. We leverage mergers and acquisition to acquire innovations (patents, R&D capabilities)
67. We enter a number of partnerships with universities and/or research centers
68. We leverage partnerships with other companies working in the same industry
69. We leverage partnerships with other companies working in a different industry
70. We co-invent with the clients
71. We leverage an industry network where we share innovation resources and capabilities
72. We participate into EU/government funded research projects
73. We do not have partnerships or collaborations of any type

Benefits Realisation

E4. For the following business KPIs please indicate what percentage of improvement has been linked to the adoption of advanced technologies:

[SINGLE SELECT]

ANSWERS: Increase %: None (0%), Less than 5%, 5%–9%, 10%–24%, 25%–49%, 50% plus, don't know

74. Cost reduction
75. Revenue and/or profit growth
76. Time efficiency
77. Product/service quality
78. Customer satisfaction
79. Business model innovation
80. Number of new products or services launched

SECTION F: ADVANCED TECHNOLOGY SKILLS

F1. Which skills are most needed in the organization to implement advanced technology-based products and projects?

[SELECT UP TO THREE]

81. General IT skills
82. Professional IT skills (e.g. programming)
83. Management skills
84. Customer handling skills
85. Problem solving skills
86. Foreign language skills
87. Technical, practical or job-specific skills
88. Numerical and data analytics skills

F2. For each selected skill, to what extent are the required skills available inside the organization?

[SINGLE SELECT – for the skills selected in F1]

89. We don't have the skills at all yet
90. We have a significant shortfall
91. We have a small shortfall
92. We have all the skills we need

F3. For each selected skill, please estimate how difficult it will be in your company to acquire the required skills in the next 2-3 years.

[SINGLE SELECT – for the skills selected in F1]

93. Not at all difficult
94. Slightly difficult
95. Moderately difficult

96. Very difficult
97. Extremely difficult

Close

Thank you for your time and help today. Before I go, may I confirm that my name is {INTVRS->NAME} calling from……………………… All your replies will be treated in the strictest of confidence and in accordance with the Code of Conduct of the Market Research Society and ESOMAR. Should you require any further information, you may contact …………………………….

Alternatively, you may contact the Market Research Society on

|[SELECT BELOW]| or log onto our web site ……………………….

Thank you very much for your help. Have a good day.

Goodbye.

Appendix D: LinkedIn representativeness analysis

Reflections on the suitability of LinkedIn

LinkedIn is the largest professional network platform with rich information like profile summary, job title, job description and field of study, which can be used for the identification of skilled professionals in advanced technologies. **It represents the single most comprehensive source currently available for the construction of technology-specific skills related indicators**.

Compared to highly resource intensive alternatives such as surveys it represents the most cost effective alternative considering not just the cost of running the analysis once but also the potential to run the analysis at regular intervals and on demand (e.g. during and after the Covid-19 crisis). The use of LinkedIn gives practitioners the flexibility not only to define any combination of skills but to do so at the national, regional or even local level.

To leverage the potential of the database for the purpose of policy making the indicators derived from the data need to be corrected for the under or over represented groups in the population which can be done using post stratification techniques. The lack of representativeness for the population characteristics is expected when using Big Data databases and the objective, as in every statistically sound survey analysis, is to apply the right method to derive correct estimates of the population. The weighting approach applied is described in section 8.2 Weighting approach.

Considerations to be taken into account when using LinkedIn data include the following points:

- LinkedIn is a voluntary professional networking platform for which subscription is voluntary. This implies that registered users have chosen to sign up, leading to self-selection into the sample. Hence, as the selection process is not random but voluntary, the LinkedIn sample is not a random sample. Secondly, the self-selection of LinkedIn users implies that they chose to join based on rational arguments, and only those who find utility in joining will do so. This is likely to create bias as not everyone has the same utility of joining LinkedIn depending on various factors such as geographical location, sector of activity and plausibly level of education. This is supported by the data, as one can easily observe differences in popularity of LinkedIn between countries and sectors. Hence, self-selection of LinkedIn users justifies the expected lack of representativeness of the active population.
- Using the LinkedIn tool to harvest data is very powerful and provides practitioners the flexibility to monitor skills supply in a way that has not been possible using traditional data sources. It is based on the algorithm developed by LinkedIn. Access to the raw data for an extended verification of the results is not possible but it is possible to manually check the profiles returned by queries to assure the good performance of the queries. It should also be noted that for instance when looking for the share of population with specific skills, it is not possible to assess the level of the skill, nor to distinguish between academic knowledge and industry knowledge. However, skills supply in a specific industry are possible to isolate by selecting a sector which results in only professionals currently employed in the sector in focus to be returned by the query. Furthermore, the database is constructed based on the information provided by the users on their profiles. Users basically have the opportunity to claim what they want, although it would be unlikely that someone would claim a skill not at all relevant for the employment profile he/she is working in. Data is therefore dependent on users' honesty, self-assessment (what skills do I consider having?), willingness to share information and involvement in the network (how exhaustive is my profile?). This characteristic may leave room for non-accuracy of information but that would have been the same in the case of surveys.

Considerations to be taken into account when reading the representativeness analysis include:

- The LinkedIn database suffers from missing data points such as for instance the level of education. This does not compromise the indicators but rather the possibility to run a comprehensive representativeness analysis.
- Another limitation in performing a compreshensive representativeness analysis by comparing the LinkedIn database, with the data retrieved from Eurostat is that the two datasets have different origins and hence there are mismatches in the definition of some categories. For example, the educational attainment categories on LinkedIn (masters' degree; bachelor's degree; high school) are different from Eurostat (tertiary education; upper secondary and post-secondary non tertiary education; lower than primary, primary and lower secondary education). The same kind of mismatch exists for skills and sector. These differences affect the assessment

of representativeness as the comparisons between the two datasets have to be made based on criteria that are not identical.

Approach to test the representativeness of LinkedIn

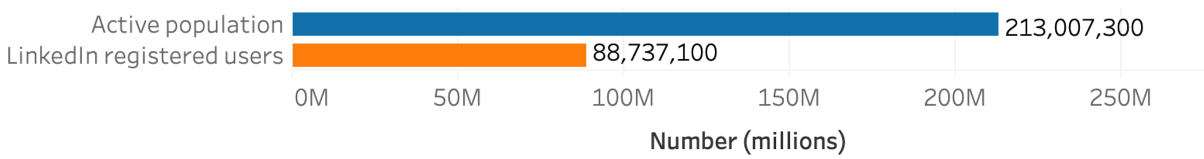
To perform the test of representativeness of LinkedIn we proceeded in two stages. First, the two datasets notably LinkedIn and Eurostat (active population) have been compared based on key statistics. These descriptive statistics show if the two populations behave similarly regarding different key aspects: entire workforce, educational attainment, gender and the science sector. Similar behaviors and figures tend to indicate that the sample represents well the population. Second, the representativeness of LinkedIn has been statistically tested on the same aspects through X-squared tests. These tests allow to check whether the difference in the behavior of the two populations is statistically significant or not, and therefore whether the sample fail to represent the population, or not.

Descriptive statistics comparing Eurostat data and LinkedIn aggregates

Workforce

The comparison of the EU27 workforce and the number of EU27 LinkedIn users in terms of absolute numbers shows that the active population of the EU27 is 213 million while 88.7 million Europeans are registered on LinkedIn. In other words, 41.6% of the active population is registered on the professional networking platform.

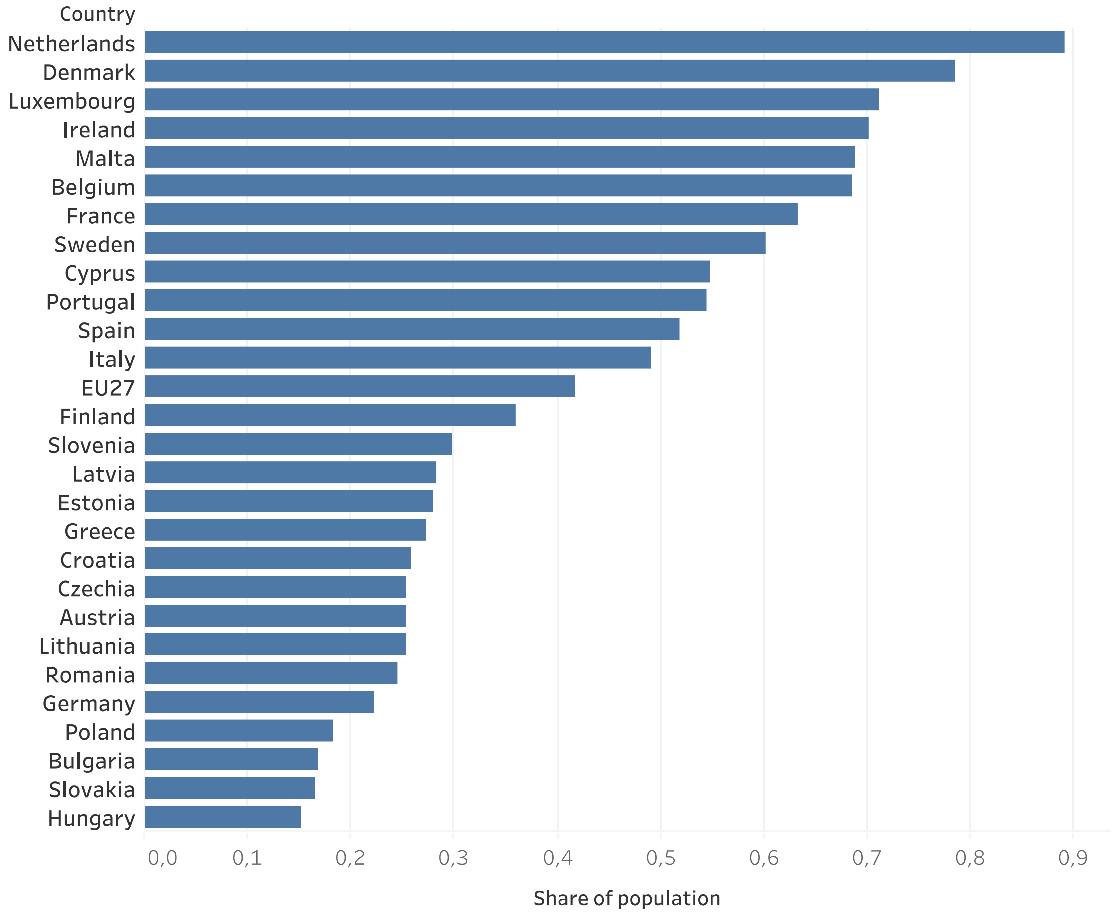
Figure 8: EU27 active population vs EU27 LinkedIn registered users



Source: LinkedIn and Eurostat (Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; 15 to 74 years old; 2018)

Behind the aggregated figure at the EU27 level, there is an important heterogeneity in the national use of LinkedIn among EU Member States, as indicated by the next figure. Indeed, in some EU countries, the number of LinkedIn users is marginal, while it is widely spread in others. In particular, Hungary, Slovakia, Bulgaria and Poland display the lowest use of LinkedIn, with less than 20% of the population registered on the platform. On the other hand, Netherlands and Denmark are the countries where LinkedIn is the most popular, with more than 75% of the active population registered (see Figure on the next page).

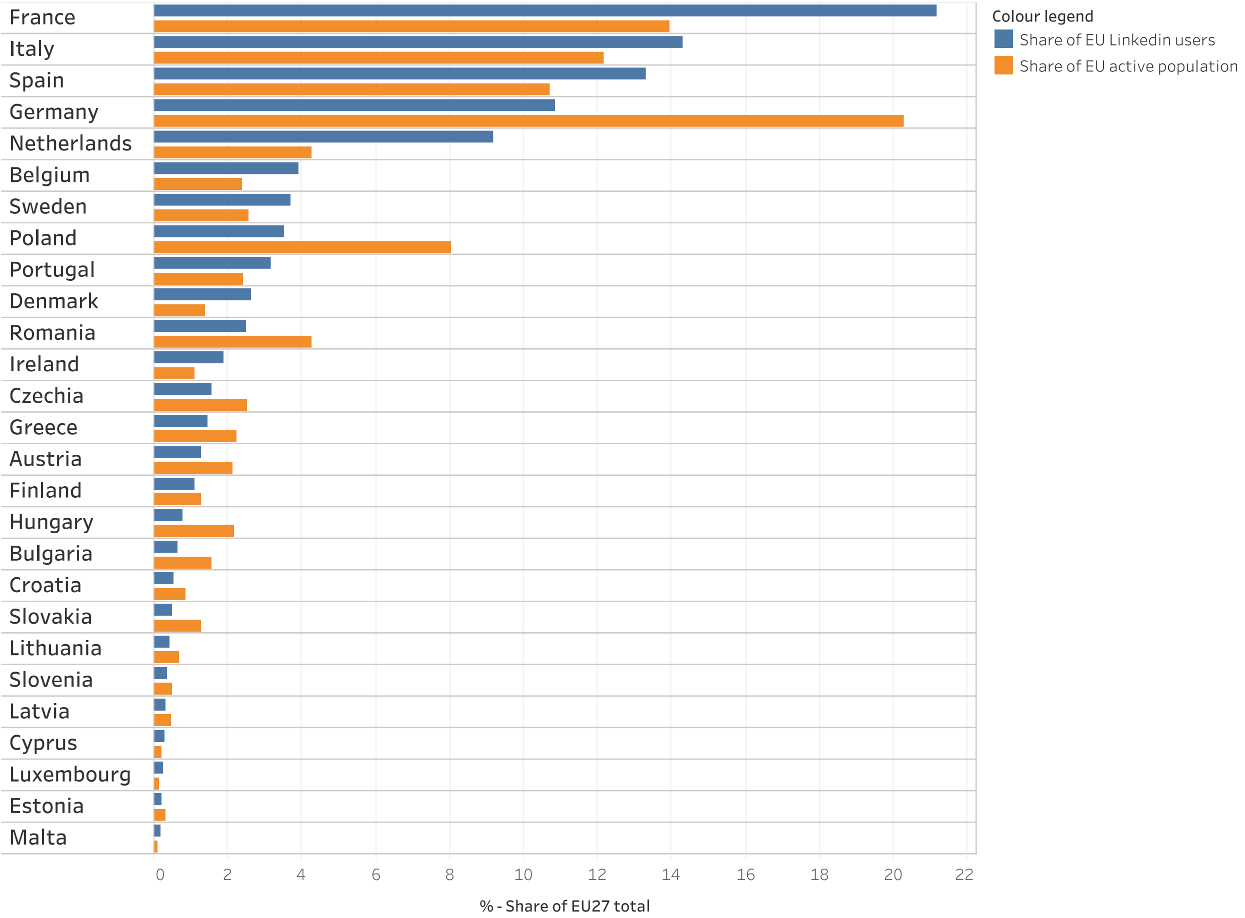
Figure 9: Share of active population registered on LinkedIn by country



Source: LinkedIn and Eurostat (Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; 15 to 74 years old; 2018)

As a result of the heterogeneity in the use of LinkedIn between EU Member States, the LinkedIn population does not reflect the EU population. Indeed, the countries where the use of LinkedIn is rare are underrepresented on the platform, while the countries where the use of LinkedIn is widespread are overrepresented. Figure 10 compares the share of the EU workforce and of the EU LinkedIn population of each country, and highlights the mismatch between them. For example, while the active population of Poland and Romania accounts for 8.03% and 4.25% of the total EU active population respectively, they only represent 3.53% and 2.5% of the EU LinkedIn users. On the contrary, Netherlands and Denmark represent 9.16% and 2.64% of the LinkedIn users although they only account for 4.28% and 1.4% of the EU active population. In total, 15 countries are underrepresented on LinkedIn (e.g. Germany) and 12 are overrepresented (e.g. France).

Figure 10: Share of total EU 27 active population vs share of total EU LinkedIn users by country



Source: LinkedIn and Eurostat (Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; 15 to 74 years old; 2018)

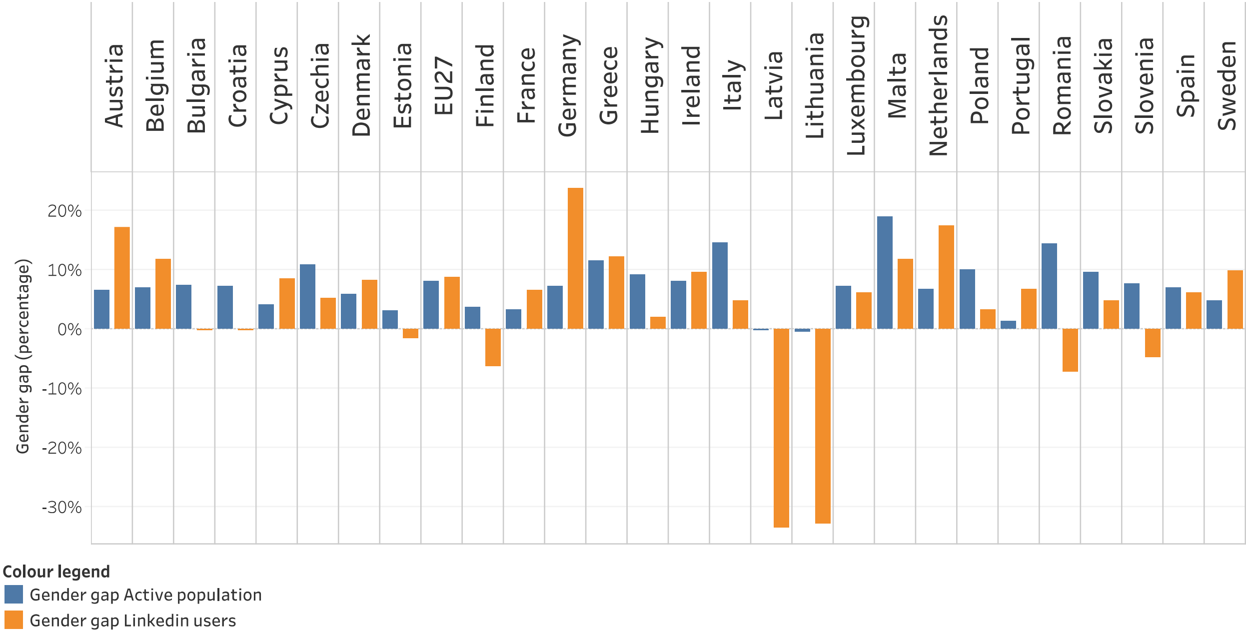
Gender

In order to assess the representativeness of the LinkedIn population in terms of gender proportions, we use the gender gap.[11] Figure 11 illustrates the gender gap that takes place in the active population and among the LinkedIn registered users. At the EU level, the gender gap on LinkedIn is comparable to the gender gap in the active population, with respective values of 8.62% and 7.95%. Regarding gender proportions, the LinkedIn population is therefore representative of the active population at the European level. However, among EU Member States, heterogeneity is observed.

Some countries display higher gender gaps on LinkedIn than in the active population. In particular, Austria, Germany and Netherlands display the most important gender gap on LinkedIn despite a limited gender gap in the active population. On the contrary, there are countries where the gender gap is reduced on LinkedIn compared to the active population, or even of opposite sign. Indeed, Estonia, Finland, Slovenia and Romania have a negative gender gap on LinkedIn (more women than men) but a positive one in the active population. This indicates a high propensity of women to register on LinkedIn. The same trend occurs in Lithuania and Latvia where the gender gap is negative both among the LinkedIn users and the active population, but is more pronounced on LinkedIn.

[11] The gender gap is calculated as the difference between the percentage of the labour market constituted of men and the percentage of the labour market constituted of women. The classification used in the case of the gender gap is therefore the same as the presence of women on the labour market.

Figure 11: Gender gap in active population vs LinkedIn users

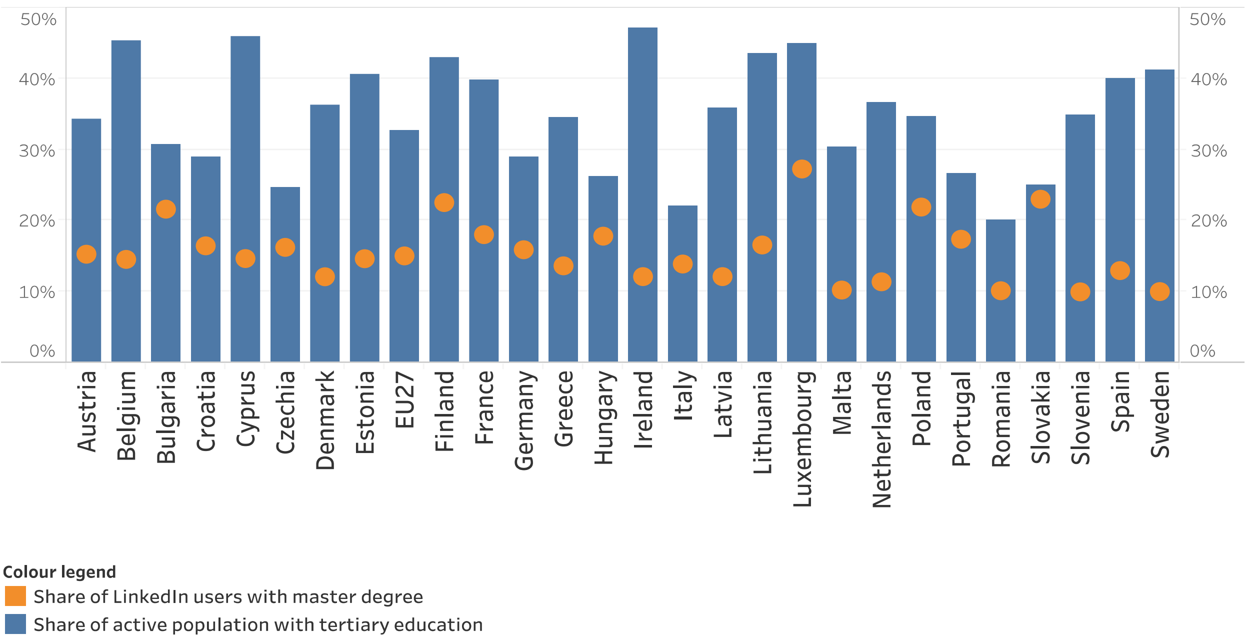


Source: LinkedIn and Eurostat (Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; Females and Males; 15 to 74 years old; 2018)

Educational attainment

Regarding the educational attainment, we first analysed the highest educated share of population both in LinkedIn and in Eurostat data. When comparing the share of LinkedIn users with master's degree and the share of active population with tertiary education, one can observe that the share of population with tertiary education is smaller for the LinkedIn users than for the active population in all countries. The first straightforward explanation is the underrepresentation of the population with a master's degree among LinkedIn users. However, more plausibly, the low shares of tertiary educated workers on LinkedIn might as well be explained by the non-systematic registration of educational attainment on LinkedIn. Since the information on the educational attainment is missing for 68.7% of the LinkedIn sample, the share of those who are registered as having a master on the total users is low. Additionally, only the LinkedIn users having a master's degree are accounted for in the LinkedIn ratio, while tertiary education includes other forms of higher education in the active population ratio.

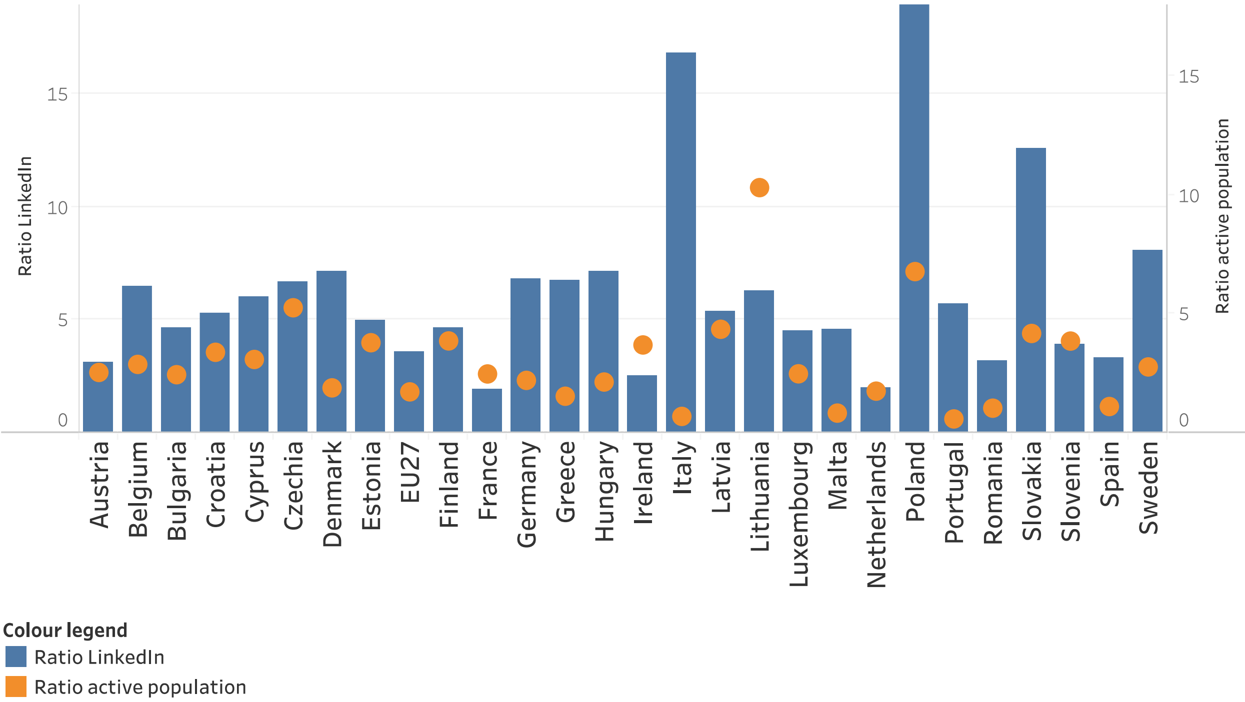
Figure 12: Share of highest educated among LinkedIn users vs active population



Source: LinkedIn and Eurostat (Active population by sex, age and educational attainment [lfsa_agaed] – ISCED 2011 Levels 5-8; 15 to 74 years old; 2018)

In order to avoid the bias caused by the missing information on educational attainment, we use a ratio for the active population and for the LinkedIn population. The structure of the ratio takes into account both extremes of the education distribution and it is constructed in the following way. The share of people with highest educational attainment (master's degree for the LinkedIn users, tertiary education for the active population) on the share of people with the lowest educational attainment (high school for LinkedIn users and less than primary, primary and lower secondary education for active population). Comparing both ratios allows to see if the proportions between highly educated and low educated are similar in the two populations without being distorted by the missing information. From Figure 13 one can observe that in most countries (19 EU Member States and EU27 average), the ratio of the highest educated on the lowest educated is higher among LinkedIn users than in the active population. In other words, among the LinkedIn users for whom the educational attainment is available, the highly educated (master's degree) are overrepresented. This is particularly true for Italy, Portugal and Poland where the difference between the LinkedIn ratio and the active population ratio is the largest. In fact, the ratio for Poland is so high that it is not fully visible on Figure 13 (57.4). It is interesting to note that in the case of Italy and Portugal, the important difference between the two ratios is linked to the large share of the active population with the lowest educational attainment. It can be deducted that while this fringe of population reduces the active population ratio, it does not have the same effect on the LinkedIn ratio because it is not present among LinkedIn users, i.e. underrepresented in the LinkedIn population.

Figure 13: Educational attainment ratio among LinkedIn users vs in active population



Source: LinkedIn and Eurostat (Active population by sex, age and educational attainment [lfsa_agaed] – ISCED 2011 Levels 0-2 & 5-8; 15 to 74 years old; 2018)

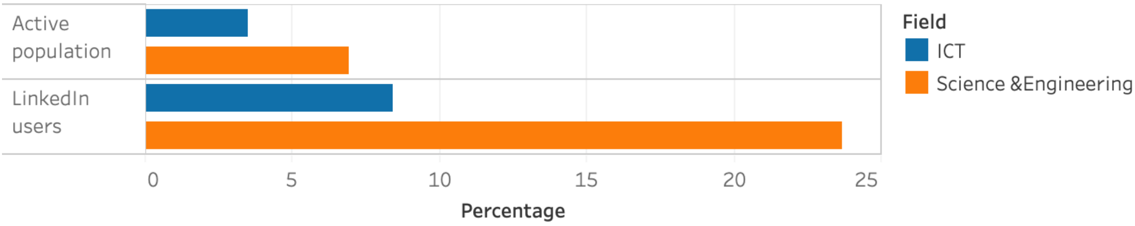
There are few cases where the active population ratio is more important than the LinkedIn ratio, but the difference is generally quite small (<1.5). The only exception is Lithuania, where the difference of ratio therefore indicates that on LinkedIn the lowest educated are overrepresented and/or the highest educated underrepresented.

In general, the lowest educated are underrepresented and/or the highest educated are overrepresented in most of the EU Member States (including EU27 average). In terms of educational attainment, the LinkedIn population is not representative of the active population.

Science & Engineering and ICT

The representativeness of the LinkedIn sample can also be assessed against the importance of different knowledge activities among the population. We compare the relative importance of the Information and Communications Technology population (ICT) and the Science and Engineering population (SE). In Figure 14 the number of people working in ICT and SE is taken as the percentage of the active population and of the LinkedIn users. 6.92% of the active population works in SE[12] and 3.49% in ICT[13], while 23.68% of LinkedIn users are from the SE sector and 8.38% from the ICT sector.

Figure 14: Share of EU active population vs share of EU LinkedIn users in Science & Engineering vs in ICT



Source: LinkedIn and Eurostat (A. Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; 15 to 74 years old; 2018. B. Employed ICT specialists by sex [isoc_sks_itsps] – Males and Females; 2018. C. HRST by category, sex and age [hrst_st_ncat] – 15-74 years old; Scientists and engineers; 2018)

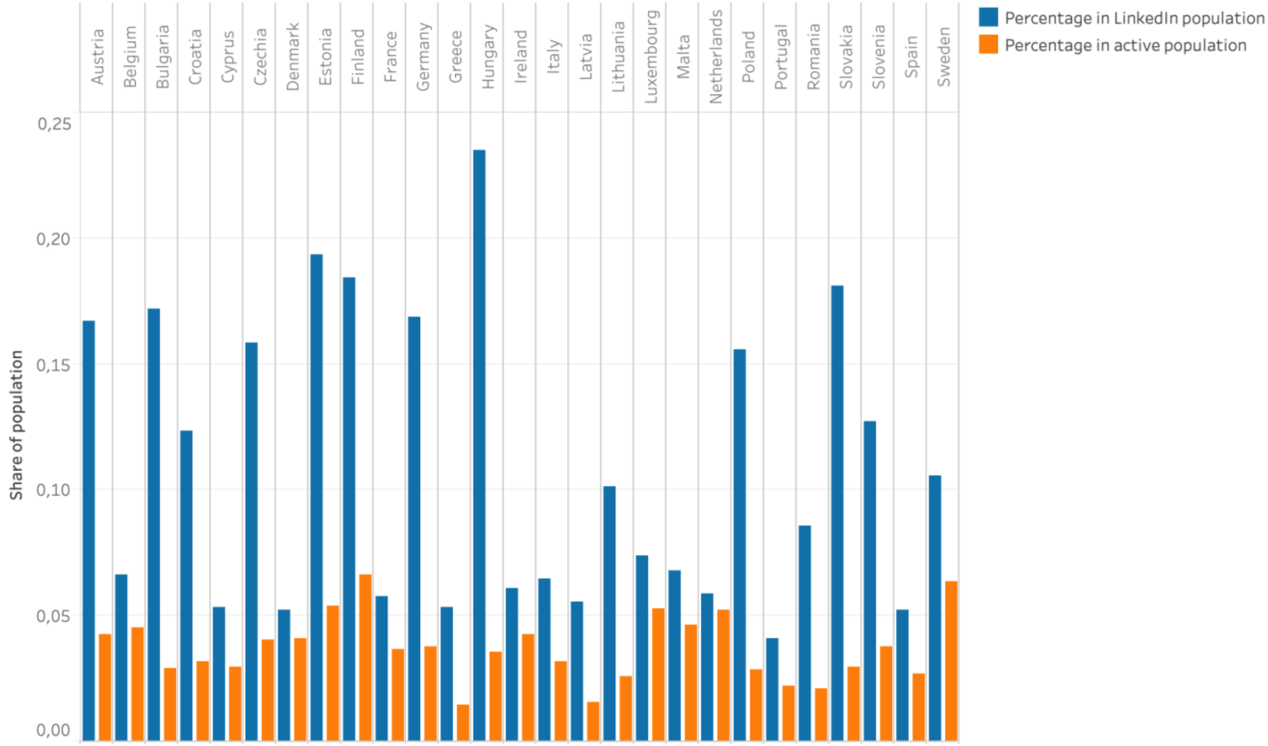
One can observe that both populations are overrepresented on LinkedIn, as they represent a larger share in the LinkedIn population than in the active population. This trend is even more pronounced for the SE sector: the share of LinkedIn users in SE is more than 3 times more important than the share of active population in SE. For the ICT sector, this figure is around 2.4. The overrepresentation of the ICT and SE sectors on LinkedIn does not only concern the EU27 as a whole, but it is persistent among all EU Member States. Figures 15 and 16 show that in all countries the share of population in ICT and SE is higher among the LinkedIn users than in the active population.

However, this trend occurs to different extents. In particular, Hungary has among the largest gaps for both ICT and SE, along with Finland for SE and Bulgaria, Estonia and Slovakia for ICT. Ireland and Luxembourg are interesting cases because the gaps between the share of LinkedIn population in SE and the share of active population in SE are among the largest; while in ICT this gap is very limited. The best performers in terms of representativeness of the LinkedIn sample, i.e. the EU Member States with the smallest gap between the LinkedIn population and the active population, are Romania, Poland and Sweden for SE, Denmark and Portugal for ICT and Belgium and Netherlands in total.

[12] Eurostat: HRST by category, sex and age [hrst_st_ncat]; Active population by sex, age and educational attainment [lfsa_agaed]

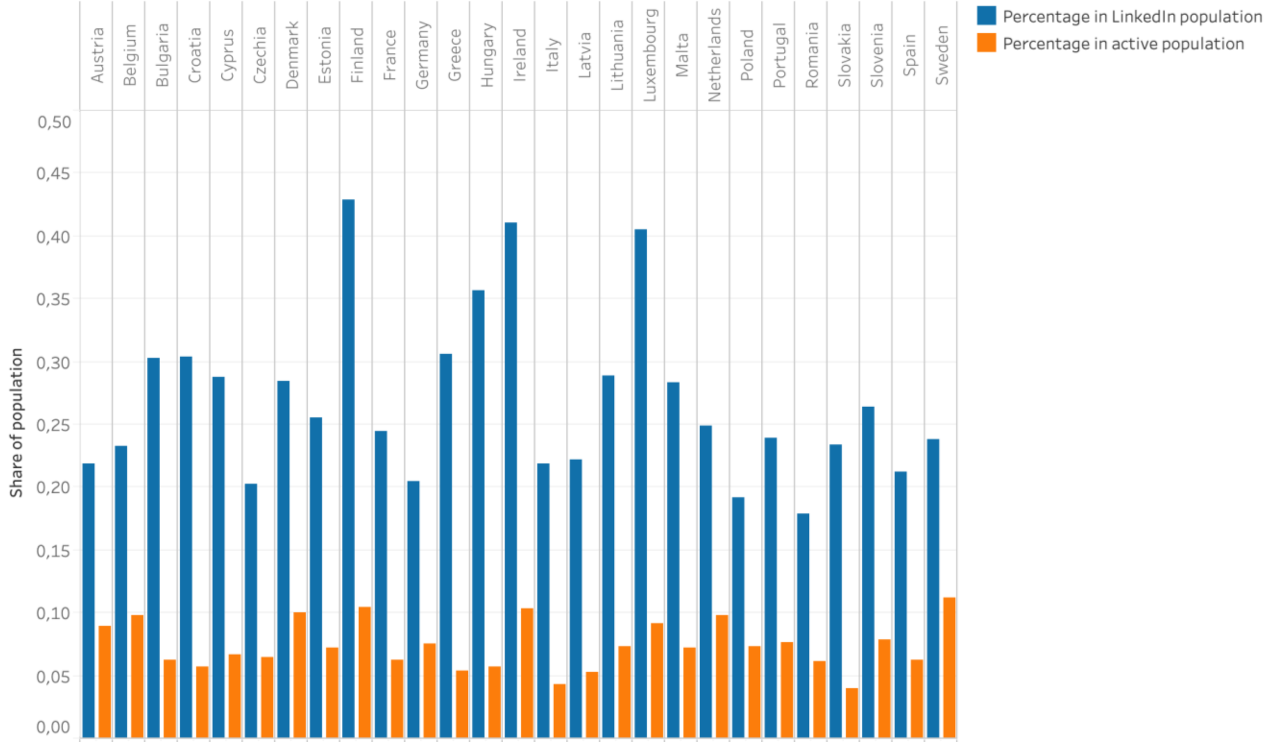
[13] Eurostat: Employed ICT specialists by sex [isoc_sks_itsps]; Active population by sex, age and educational attainment [lfsa_agaed]

Figure 15: Share of LinkedIn users in ICT vs share of active population in ICT by country



Source: LinkedIn and Eurostat (A. Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; 15 to 74 years old; 2018. B. Employed ICT specialists by sex [isoc_sks_itsps] – Males and Females; 2018)

Figure 16: Share of LinkedIn users in Science and Engineering population vs share of active population in Science and Engineering population by country



Source: LinkedIn and Eurostat (A. Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; 15 to 74 years old; 2018. B. HRST by category, sex and age [hrst_st_ncat] – 15-74 years old; Scientists and engineers; 2018)

Despite these few exceptions, the population in Science & Engineering and ICT is in general largely overrepresented on LinkedIn. Hence, regarding the knowledge activities, the LinkedIn population is not representative of the active population.

In conclusion, as anticipated, LinkedIn based indicators will need to be corrected to reflect the distribution of the population for the characteristics in focus. This is because LinkedIn's popularity is different from a country to another, causing the EU Member States where it is more widespread to be overrepresented. Moreover, there is a misrepresentation of the educational attainment as the ratio between the highest educated and the lowest educated is considerably more important on LinkedIn than in the active population. Similarly, the prevalence of LinkedIn depends on the knowledge activity. The population in Science & Engineering is overrepresented, as well as the Information & Communication Technology population to a lesser extent. The weighting mechanism to correct for the lack of representativeness is described in section 8.2 Weighting approach.

Statistical testing

Beyond the comparison of the LinkedIn population and the active population in terms of descriptive statistics, the representativeness of LinkedIn has been also assessed through statistical testing. The X-squared tests compare the observed frequencies (i.e. derived from the LinkedIn population) and the expected frequencies (i.e. derived from the active population) and assess if the difference between them is statistically significant or not. In other words, they test if the frequencies correspond to the same population or if, on the contrary, the LinkedIn sample is not representative of the active population.

We perform the X-squared tests[14] with regard to the importance of the national workforce, the population's educational attainment, the gender proportions and the prevalence of ICT and SE. Each test has been run for the EU27 and by country (apart from the national workforce which is obviously not tested at the level of EU27). The tests are unequivocal as they all display the same result: the LinkedIn population is not representative of the active population.[15]

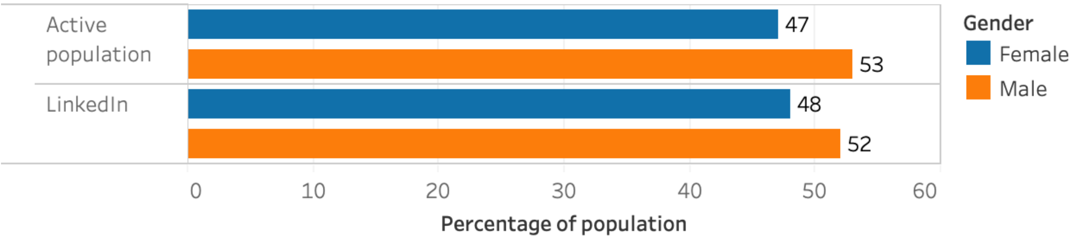
[14] The X-squared tests are run with the statistical software STATA.
[15] The X-squared tests reject the null hypothesis of representativeness.

Comparison of LinkedIn population in the EU27 and the US

The networking platform LinkedIn is more popular in the United States than in the EU27, as 164.98 million Americans are registered on LinkedIn, i.e. 100.88% of the US active population, against 41.6% in the EU27. In fact, the US even has more nationals registered on LinkedIn than accounted in the active population (as indicated by the percentage greater than 100). This is very likely to be due to the use of LinkedIn among non-active parts of the population, such as students and retirees. Given the prevalence of LinkedIn in the US, it is of interest to assess its representativeness, and to compare it with EU27.

In order to analyse the representativeness in terms of gender, we compare the proportions of males and females in the labour force and in the LinkedIn population. As indicated by the Figure below, the active population in the US is composed of 53% of males and 47% of women, against 52% and 48% on LinkedIn. The figures are therefore similar, even if the gender gap is slightly reduced on LinkedIn, going from 6% in the labour force to 4%.

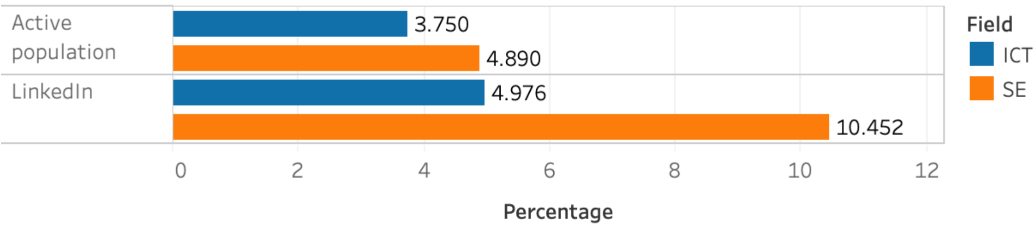
Figure 17: Gender proportions in the US active population vs among the US LinkedIn users



Source: LinkedIn 2020 and OECD 2019 (OECD Data – Labour force)

As it was the case in the EU27, some knowledge activities are overrepresented on LinkedIn. Figure 18 shows that the shares of the LinkedIn population in the ICT and SE sectors are larger than the corresponding shares in the active population. However, this trend occurs to a lesser extent than in the EU27. In particular, the share of the LinkedIn users in the ICT sector is 'only' 33% larger than the share of the active population in ICT. For the SE sector, the LinkedIn share is 2.14 more important than the active population share, indicating a pronounced overrepresentation of the SE population on LinkedIn, although still smaller than for EU27.

Figure 18: Share of US active population vs share of US LinkedIn users in Science & Engineering vs in ICT



Source: LinkedIn 2020, National Science Foundation 2018 (Individuals in S&E occupations as a percentage of all occupations – USA; 2018), OECD 2017 (OECD Digital Outlook 2017 - Share of ICT specialist employment; 2014)

Keywords used in LinkedIn queries

Technology	Keyword
Cybersecurity	cybersecurity
Cybersecurity	Intrusion detection
Cybersecurity	malware detection
Cybersecurity	cloud security
Cybersecurity	cybercrime investigation
Cybersecurity	cyberthreat intelligence
Cybersecurity	cryptography
Cybersecurity	DLP (data loss prevention)
Cybersecurity	malware analysis
Cybersecurity	IDP (identity provider)
Cybersecurity	vulnerability assessment

Cybersecurity	Certified Information Security Manager (CISM)
Cybersecurity	Computer forensics
Cloud	cloud services
Cloud	cloud infrastructure
Cloud	Google cloud platform
Cloud	Sap Cloud platform
Cloud	SAP Hana
Cloud	anything as a service (Xaas)
Cloud	software as a service (SaaS)
Cloud	platform as a service (PaaS)
Cloud	infrastructure as a service (IaaS)
Cloud	private cloud
Cloud	hybrid cloud
Cloud	cloud computing
Cloud	edge computing
Cloud	High performance computing
Cloud	Serverless computing
Robotics	Robotics
Robotics	robot
Robotics	robotic surgery ((we added this but the hits are already captured by the keyword 'robotics')
Robotics	human-robot interaction (we added this but the hits are already captured by the keyword 'robotics')
Robotics	drones
IoT	connected devices
IoT	internet of things (IoT)
IoT	edge computing
IoT	robotic process automation
IoT	wireless sensor networks
IoT	embedded systems
IoT	cyber-physical systems
IoT	smart cities
AI	Artificial Intelligence (AI)
AI	biometrics
AI	cognitive computing
AI	computer vision
AI	deep learning
AI	machine learning
AI	natural language processing
AI	natural language understanding
AI	naural language generation
AI	reinforcement learning
AI	speech recognition
AI	supervised learning
AI	unsupervised learning
Big Data	Big Data analytics
Big Data	Hadoop
Big Data	real time data
Big Data	Yarn
Big Data	teradata warehouse architecture
Blockchain	Blockchain
Blockchain	ethereum
Blockchain	bitcoin
Blockchain	cryptocurrency
Blockchain	crypto
Blockchain	distributed ledger technology
Blockchain	hyperledger
Augmented virtual reality	augmented reality
Augmented virtual reality	virtual reality
Augmented virtual reality	computer generated imagery
Augmented virtual reality	mixed reality
Connectivity	connected devices
Connectivity	connectivity
Connectivity	M2M
Connectivity	5G

Connectivity	SD-WAN
Connectivity	home automation
Mobility	Unmanned vehicles
Mobility	Electric vehicles
Mobility	Internet of Vehicles
Mobility	autonomous vehicles
Mobility	autonomous vehicles
Mobility	Navigation, intelligent transport systems
Micro Nano electronics	microelectronics
Micro Nano electronics	nanoelectronics
Micro Nano electronics	Integrated Circuits
Micro Nano electronics	CMOS
Micro Nano electronics	Electronics Packaging
Micro Nano electronics	Micro processors
Micro Nano electronics	na
Micro Nano electronics	Thin Films
Micro Nano electronics	MEMS
Nanotech	Nanotechnology
Nanotech	nanobiotechnology
Nanotech	nanomedicine
Nanotech	nanostructures
Nanotech	nanocomposites
Photonics	Photonics
Photonics	fiber optics
Photonics	optical fiber
Advanced Materials	Advanced Materials
Advanced Materials	nanomaterials
Advanced Materials	optical materials
Advanced Manufacturing	3-D Printing
Advanced Manufacturing	Additive manufacturing
Advanced Manufacturing	Advanced Materials
Advanced Manufacturing	biomaterials
Advanced Manufacturing	Computer Aided Design
Advanced Manufacturing	Cyber Physical System
Advanced Manufacturing	Embedded systems
Advanced Manufacturing	flexible manufacturing
Advanced Manufacturing	High performance computing
Advanced Manufacturing	Industrial Robots
Advanced Manufacturing	Industry 4.0
Advanced Manufacturing	nanomaterials
Advanced Manufacturing	Nanotechnology
Advanced Manufacturing	optical materials
Advanced Manufacturing	polymer science
Advanced Manufacturing	Rapid Prototyping
Advanced Manufacturing	real time systems design
Advanced Manufacturing	robot
Advanced Manufacturing	semiconductor device
Advanced Manufacturing	Smart Manufacturing
Advanced Manufacturing	smart materials
Advanced Manufacturing	Tissue Engineering
Industrial Biotechnology	biochemical engineering
Industrial Biotechnology	biodegradable polymers
Industrial Biotechnology	biofuels
Industrial Biotechnology	biopharmaceuticals
Industrial Biotechnology	bioplastics
Industrial Biotechnology	bioengineering
Industrial Biotechnology	biochemistry

Appendix E: ATI application areas, subdomains and keywords

Digital technology	Subdomain	Keyword
Robotics	Collaborative robots	Trainable systems; automation; physical human robot interfaces; assisting surgery and diagnosis; artificial parts; therapeutic use; assistive technology & apparatus; maintenance and cleaning; sensing and interpretation of environment; patient care and logistics;
Robotics	Industrial robot	Manufacturing Robotics; processing equipment & machinery; inspection and maintenance; long term autonomy; warehouse automation, lift & conveyor; agricultural & dairy machinery;
IoT	Secure and trusted data spaces	Data access, sharing, valorisation; data ecosystem; cloud; edge computing; data analytics & processing;
IoT	Smart and interconnected devices	Measurement & instruments; connected machinery; connected sensors; circuits & semiconductors; printing devices & apparatus; radar & signal generators; audio & video receiver and reception devices; portable devices;
IoT	Data infrastructure & networks	Wireless networks; data platforms; 5G; cellular; trusted and secure infrastructure, data infrastructure; high-performance computing (HPC); computer (PC); human machine interface (HMI); cyber-physical production systems (CPPS);
AI	Machine Learning (ML)	Automated machine & other forms of learning; generative adversarial network; generative model; adversarial network; anomaly detection; neural network; pattern & automatic recognition; automatic classification & control; probabilistic model; recommender system; bagging; bayesian modelling; boosting; support vector machine; collaborative & content-based filtering; data mining; ensemble method;
AI	Knowledge representation; Automated reasoning; Common sense reasoning	Case-based reasoning; inductive programming; causal inference; information theory; causal models; knowledge representation & common sense reasoning; latent variable models; semantic web; fuzzy logic; data processing & analysis;
AI	Planning and Scheduling; Searching; Optimisation	Bayesian, metaheuristic & stochastic optimisation; hierarchical task network; constraint satisfaction; evolutionary & genetic algorithm; gradient descent; data storage;
AI	Natural Language Processing (NLP)	Chatbot; natural language generation & understanding; computational linguistics; machine translation; conversation model; coreference resolution; sentiment analysis; text classification; information retrieval; text mining;
AI	Computer vision; Audio processing	Recognition technology; sensor network; camera & image processing; visual search; computational auditory scene; display and video console, including screen, projector, LCD panel; sound & speech processing & recognition;
Security	Cryptography	Cybercrime of digital identities and assets; Blockchain and distributed ledger technology (DLT); privacy; quantum technologies;
Security	Intrusion detection and malware mitigation	Threat intelligence, antivirus; fraudulent activity detection software; infrastructure protection: firewall;
Security	Network and systems	Network monitoring; embedded, vehicular, and industrial control systems (e.g. SCADA); information & operating systems, pervasive systems; biometric identification; security middleware tools; smart card OS; satellite systems and applications; cameras & televisions; circuits; burglar alarms;
Big Data	Data collection, organisation and management	Sound & speech data; visual & image data; data storage; recognition technology; sound, speech & music recognition; intelligent user interface;
Big Data	Analytics and discovery	Data, image, speech & sound processing; central processing unit (CPU); decision analytics; data analytics; analytics platform; tensor & graphics processing unit; inductive programming; causal inference; information theory; causal

Digital technology	Subdomain	Keyword
		models; latent variable models; graphical models; semantic web; fuzzy logic;
Big Data	Decision support and automation	Case-based reasoning; common-sense reasoning; knowledge representation & reasoning; decision support; agent-based modelling; negotiation algorithm; game theory; swarm intelligence; q-learning; computational economics;
Enterprise Mobility	Network & telecommunication systems	Network infrastructure; satellite & radio communication; radiolocation; signalling; traffic management systems; 5G; traffic control technology; cameras;
IT for Mobility	Autonomous vehicles	Unmanned vehicle; electric & autonomous vehicle; display; instruments & instrument panel; navigation; vehicle data;

The table is based on the following studies:

- Samoili, S., López Cobo, M., Gómez, E., De Prato, G., Martínez-Plumed, F., and Delipetrev, B., AI Watch. Defining Artificial Intelligence. Towards an operational definition and taxonomy of Artificial Intelligence, EUR 30117 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-17045-7, doi:10.2760/382730, JRC118163.
- NAI-FOVINO, I.; NEISSE, R.;'LAZARI, A.; RUZZANTE, G.; POLEMI, N.; FIGWER, M. European Cybersecurity Centres of Expertise Map - Definitions and Taxonomy. EUR 29332 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-92956-4, doi:10.2760/622400, JRC111441
- euRobotics (2014). SPARC: The partnership for Robotics in Europe. Strategic Research Agenda for Robotics in Europe 2014-2020. Obtained from: https://www.eu-Robotics.net/sparc/upload/topic_groups/SRA2020_SPARC.pdf
- C-ITS Platform (2015). Working group 6: Access to in-vehicle resources and data. Obtained from: https://ec.europa.eu/transport/sites/transport/files/facts-fundings/tenders/doc/specifications/2015/s248-450626-annex6-report.pdf
- SVC 6 – INDUSTRIAL INTERNET OF THINGS (2019) ESTABLISH A RELIABLE, EFFECTIVE, SAFE AND SUSTAINABLE INDUSTRIAL DATA ECOSYSTEM IN EUROPE Main Report.
- Strategic Value Chain Cybersecurity (2019) Strategic Value Chain Report Cybersecurity.

Appendix F: Keywords of the text-mining analysis

Technologies	Keywords (English)
Advanced Materials	advanced material
	Advanced Materials
	advanced composite
	nanomaterial
	nanomaterials
	polymer
	functional material
	functional materials
	thermoplastic composite
	polymer science
	optical material
	optical materials
	electronic material
	electronic materials
	materials technology
	innovative material
	innovative materials
	material engineering
	new material
	new materials
	graphene
	sustainable material
	organic-based materials
	green raw materials
	biomaterials
	biomaterial
Industrial Biotechnology	bioenzimes/ bioenzymes
	biochemicals
	industrial enzymes
	industrial biotechnology
	white biotechnology
	bioengineering
	biomanufacturing
	bioelectronics
	biodegradable polymers
	biochemistry
	biopharmaceuticals
	enzyme
	biocatalyst
	bio-based
	bioprocess

	microbial
	phosphate
Micro- and nanoelectronics	microelectronics
	microtechnology
	microchip
	nanoelectronics
	Integrated Circuits
	CMOS, Complementary Metal Oxide Semiconductor
	FPGA, field-programmable gate array
	FDSOI, Fully Depleted Silicon On Insulator
	RISC, Reduced Instruction Set Computer
	neuromorphic
	quantum chip
	chip-based
	Complex SOC, system on a chip
	micro-electromechanical
	MEMS, Microelectromechanical systems
	NEMS, Nanoelectromechanical systems
	Micro processor chips
Photonics	LED
	OLED
	photonic
	photonic
	photodiode
	photodetector
	photodetectors
	phototransistor
	superluminescent
	optronics
	laser-based
	light-based
	laser technology
	plasma-based
	light scattering instruments
	optoelectronics
	biophotonics
	photovoltaics
	photonic computing
	optical fiber
	fiber optics
Nanotechnology	nano
	nanotechnology
	nanotech
	nanoparticles

	nanobiotechnology
	nanomedical technology
	nano
	nanobot
	nanostructured materials
	nanocomposites
Advanced Manufacturing technologies	3-D Printing
	additive manufacturing
	Advanced Manufacturing
	agile Manufacturing Systems
	cloud Manufacturing
	computer Aided Design
	computer Aided Manufacturing
	CAD
	computer Control Systems
	computer integrated manufacturing
	embedded systems
	factory automation
	Flexible Manufacturing Systems
	High precision processing
	High-performance processing
	High-performance production
	industrial robots
	Industry 4.0
	intelligent equipment
	precision Engineering
	rapid Prototyping
	real Time Systems
	robots
	semiconductor device manufacture
	sensor-based equipment
	smart manufacturing
Robotics	robotics
	robot-powered
	robotic
	robot
	drone
	cobot
	stockbot
	sewbot
	harvest robots
	exoskeleton
	Intelligent process automation
	robotic process automation

	automate
	automation
Internet of Things	internet of things
	industrial internet of things
	IoT
	IIoT
	smart
	smart city
	NB-IoT, narrowband internet of things
	predictive maintenance
	LPWA, Low-Power Wide-Area
	smart factory
	smart shop
	smart device
	smart wearable
	smart home
	smart office
	smart health
	internet of care
	withings
	home control
	remote control
	fitness tracker
	medical sensor
	fleet management
	process automation
	asset tracking and management
	telemetry
	optimising processes
	location detection
	advanced sensor
	machine to machine communication
	networked devices
	connected devices
	connected objects
	connected
	LoraWan
	SigFox
	sensor
	precision
	traceability
	Smart City
	cyber phyiscal system
	safety critical system

	networked control system
	integrate web applications
	continuous exchange of data
	automated valet parking
	scalable system
	from anywhere
	remote monitoring
	remotely monitor
	remote location
	network of connected devices
Articial Intelligence	Artificial Intelligence, AI
	AI-based
	intelligent system
	machine learning
	machine intelligence
	reinforcement learning
	voice recognition
	face recognition
	sound command
	voice command
	deep learning
	cognitive computing
	natural language processing
	ML-driven solution
	AI-driven solution
	AI powered
	Natural language understanding
	Natural language interpretation
	sentiment analysis
	digital image processing
	ML based
	H2O.ai
	autonomous machine
	semantic segmentation
	chatbot
	AI bot
	virtual assistant
	virtual agents
	autopilot
	human and machine
	image recognition
	speech recognition
	biometrics
	computer vision

	semantic analysis
	neural network
Big Data	big data
	data management
	unstructured data
	data analytics
	data gathering
	data processing system
	real time information
	predictive analytics
	data service
	high volume data
	high velocity data
	high variety data
	real time data
	data-driven
	predict trends
	machine learning
	Yarn
	Hadoop
	data monetization
	data mining
	edge computing
	data warehousing
Augmented/Virtual Reality	augmented reality
	virtual reality
	extended reality
	AR content
	VR content
	fully-immersive reality
	digital information on real-world elements
	VR head-mounted display
	VR headset
	computer-generated imagery
	screenless viewer
	computer-generated sounds
	immersive experience
	Augmented Reality Platform
	advanced computer visualization
	stereoscopic camera
	virtual reality gaming
	Mixed Reality
	VR UI/UX design
	AR UI/UX design

	simulation
	simulator
	virtualisation
Blockchain	blockchain
	ethereum
	bitcoin
	cryptocurrency
	crypto
	distributed ledger
	peer-to-peer network
	chain of transactions
	hashcash

Appendix G: Crunchbase and Dealroom categories

Crunchbase categories:

Technology	Categories				
Advanced Manufacturing	3D printing	Industrial Engineering	Robotics	Industrial automation	CAD
Advanced Materials	Advanced Materials				
Artificial Intelligence	Artificial Intelligence	Natural language processing	Facial recognition, Speech recognition, Image recognition	Machine learning	Predictive analytics, Computer vision
Augmented Virtual Reality	Augmented reality	Virtual reality	Virtualisation		
Big Data	Big Data				
Blockchain	Blockchain				
Cloud computing	Cloud computing	Cloud data services	Private Cloud	Cloud management	
Connectivity	Satellite communication	Wireless			
Industrial Biotechnology	Biotechnology				
Micro- and Nanoelectronics	Electronics	Semiconductors			
IT for Mobility	Autonomous vehicles	Electric vehicles			
Nanotechnology	Nanotechnology				
Photonics	Laser	Optical communication	Lighting		
Robotics	Robotics	Drones			
IT for Security	Cloud security	Cybersecurity	Network security		
The Internet of Things (IoT)	Internet of Things	Wearables			
Sectors			**Categories**		
Agro-food	Food processing	Food and beverage			
Automotive	Automotive				
Chemicals	Chemicals	Chemicals engineering			
Electronics	Electronics	Semiconductor			
Finance	Finance	Financial services			
Medical devices	Medical devices	Health diagnostics			
Telecommunication	Telecommunication				
Textiles	Textiles				

Dealroom categories

Technologies	Search within text	Tags used					
Advanced Materials	"Advanced Materials"	composite materials	material technology				
Advanced Manufacturing	"Advanced Manufacturing"	3D printing	3D technology	fabless manufacturing	3D printing robots	silicone 3D printing	
Nanotechnology	"nanotech"	nanotech	nano technology				
Micro- and Nanoelectronics	"nanoelectronics"	microelectronics					
Industrial Biotechnology	"industrial biotech"; "biological treatment"; "bioplastics", "biopolimers" , "biochemicals" , "biopharma"	biofuels	BioTechnology	biopolymers	biochemical		
Photonics	"Photonics", "photodiodes"; "LED", "optics"; "fiber optics"	laser technology	LED Lighting	optics	fiber optics	Photonics	
Robotics	"robot", "Robotics", "exoskeleton", "drone"	Automated Technology	drones	Robotics	cleaning robot	industrial Robotics	
The Internet of Things (IoT)	"Internet of Things"	Industrial IoT	iOT automation	internet of things platform			
Artificial Intelligence	"aritificial intelligence"; "AI"; "deep learning"; "machine learning"	Artificial Intelligence	chatbot	deep learning	facial recognition	Image Recognition	machine learning
		machine vision	Natural Language Processing	object recognition	Recognition Technology	voice recognition	Computer Vision
Cybersecurity	"security", "access control", "authentication", "malware protection", "encryption"	cybersecurity	Network Security	web security	encryption	online security	
Connectivity	"connectivity"	4G	5G	connected device	WiFi	satellites	Mobile Device Management
Cloud technology	"cloud technology"	cloud technology	Cloud Computing	Cloud Infrastructure	cloud services		
Blockchain	"Blockchain"	Bitcoin	cryptoassets	cryptocurrencies	cryptographics	ethereum	Blockchain

Big Data	"Big Data"	Behavior Analytics	Big Data	Predictive Analytics	sales analytics	Big Data & Analytics	Advanced Data analytics
Augmented/ Virtual Reality	"augmented reality"; "virtual reality", "mixed reality", "screenless viewer"	augmented reality	virtual reality				
IT for Mobility	autonomous vehicles	connected vehicle	autonomous & sensor tech	connected car	Mobility		
Sectors	**Search within text**	**Tags used**					
Agro-food		food					
Automotive		automotive					
Chemicals		chemicals					
Electronics		electronics					
Finance		finance					
Medical devices		medical devices					
Telecommunication		telecommunications					
Textiles		textiles					

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