The Economics of Digital Transformation

The Disruption of Markets, Production, Consumption, and Work

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1 The foundations of the digital economy

Abstract

How did the **digital economy** come into being? This introductory chapter takes you on a quick ride through the history of the **technological revolution** that laid the foundations for the digital economy by creating lots of mobile, hyperconnected, and mightily functional **digital devices**, such as smartphones. Ever more user-friendly devices paved the ground for **digitisation**, i.e., encoding **data** in a machine-readable format. Next, we show how the exponential growth in the amount of digitised data, coupled with the advanced analytical tools of **artificial intelligence** (which we refer to as '**datafication**') is contributing to the acceleration and intensification of the **innovation** processes, changing the way societies and economies work. We conclude by describing the digital economy as it has emerged so far through multiple **digital transformations**, and by emphasising the role of **networks** that process the growing flood of data.

What is the digital economy?

You could tell that change was taking place when in 2019 UNCTAD, the UN Conference on Trade and Development, altered the traditional title of its yearly report from 'The Information Economy' to 'The Digital Economy', justifying it by the need to focus on the 'far-reaching and highly significant impacts expected from digitalization'.[1] The concept of the information economy took off at the end of the 1970s, having grown out of the idea of the **knowledge economy**, a concept that had been in use for almost two decades by then.[2] Both concepts emphasised the growing role of information and knowledge in economic processes, as part of the growing role of services, rather than industry, in first-world economies. Starting in the 1990s, the idea of the **internet economy** or the dotcom economy gathered favour.[3] In the 2010s another international organisation, the Organization for Economic Cooperation and Development (OECD), started to use the notion of the digital economy alongside the internet economy, and in 2015 it published *the Digital Economy Outlook* report which 'replaced and built upon the OECD Communication Outlook and Internet Economy Outlook' in order to 'provide a

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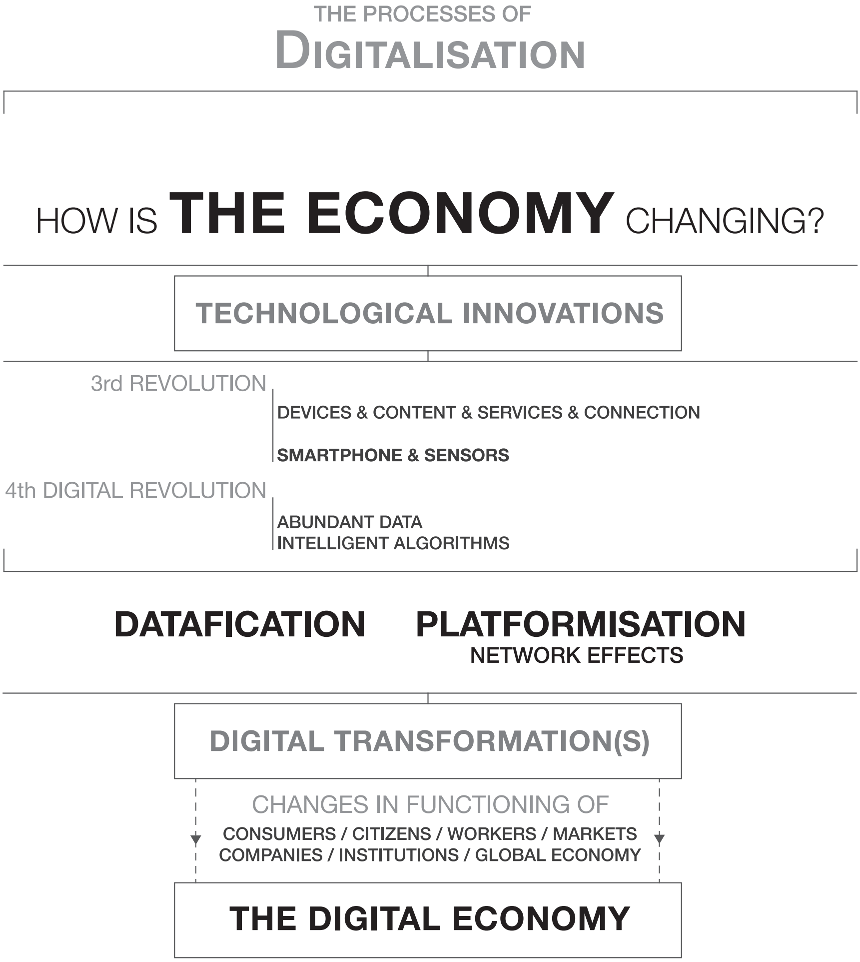

Figure 1.1 How is the economy changing? (scheme).
Source: Own elaboration.

more holistic overview of converging trends, policy developments and data in the digital economy on both the supply and demand sides'.[4] These are no mere linguistic modifications – they reflect the growing consensus among the economists close to the decision-makers that we may observe the emergence of **a new set of rules for economy**. Much less consensual is the specification of these rules leading to the definition of the digital economy.

The phrase, the **digital economy,** first appeared in the mid-1990s (albeit without a precise definition) in the title of Don Tapscott's book, *The Digital Economy: Rethinking Promise and Peril in the Age of Networked Intelligence*. Tapscott described an era in which intelligent machines and people were starting to connect through technology.[5] Equally elusive was the definition proposed in

2000 by Eric Brynjolfsson and Brian Kahin in their book *Understanding the Digital Economy: Data, Tools, and Research*. They used the term to describe 'the recent and still largely unrealised transformation of all sectors of the economy by the computer-enabled digitization of information'.[6] The first definitions proposed by the OECD (2012) and experts at the European Commission (2013) tended to conflate the digital economy with the internet economy. The OECD acknowledged that the digital economy 'enables and executes the trade of goods and services through electronic commerce on the Internet',[7] while the European Commission declared that it was 'an economy based on digital technologies (sometimes called the internet economy)'.[8]

A team appointed by the British Economic and Social Research Council[9] to study the impact of the digital economy on socio-economic development found, in 2017, that the literature on the digital economy generally identified it simply as an economy which 'functions primarily by means of digital technology, especially electronic transactions made using the Internet',[10] and is 'an amalgamation of technology and people's activities'.[11] A technical note prepared in 2017 for UNCTAD emphasised that a new digital economy is developing thanks to the implementation of advanced cyber-physical systems (connecting machines, IT systems and employees). It includes technologies and processes based 'in one way or another' on advanced information and communication solutions, such as the robotisation and automation of production, new data sources arising from mobile – and ubiquitous – internet connectivity, cloud computing, big data analytics, and artificial intelligence. These technologies 'seem poised to dramatically reduce demand for routine tasks and transform the location, organization, and content of knowledge work'.[12]

A more specific description of the digital economy was one advanced by the OECD in 2015: the digital economy is characterised by an unparalleled reliance on intangibles, the massive use of data (notably personal data), the popularity of platforms as a business model, and the difficulty of determining the jurisdiction in which value creation occurs.[13] In February 2018 the International Monetary Fund (IMF) emphasised that the 'digitalization of the economic activity can be broadly defined as the incorporation of data and the internet into production processes and products, new forms of household and government consumption, fixed capital formation, cross-border flows, and finance'.[14] In 2020 OECD, having scrutinised a range of definitions, came up with a general, bind-them-all definition of the digital economy: it 'incorporates all economic activity reliant on, or significantly enhanced by the use of digital inputs, including digital technologies, digital infrastructure, digital services and data. It refers to all producers and consumers, including government, that are utilising these digital inputs in their economic activities.'[15]

Our approach draws from the conceptual effort that OECD and International Monetary Fund experts have made, but it sets to emphasise the trends that are changing the economy.

> The **digital economy** emerges through countless, diverse, dispersed, and uneven processes of **digital transformation**, which consist in

> changing how the consumers, employees, markets, enterprises, and other organisations function. They are made possible by the development and rolling out of breakthrough technologies for producing, collecting, processing, analysing and using data, such as connected mobile digital devices, the Internet of Things, and the cloud, and, above all, algorithms of artificial intelligence. The information gained from abundant data analysed more cheaply, quickly, and efficiently by **intelligent algorithms** builds a new economic layer of the digital economy through the introduction of new and ever more personalised **digital products** (goods and services) and development of new business models based on ever-growing **networks of connected people, organisations, and machines** (such as platforms) and management prioritising on the rule of 'data-first, AI-first'.

This is, admittedly, a working definition that needs empirical grounding. In the next few chapters of the book we will flesh it out with more facts: we will show how rolling out of new digital technologies contributes to the digital transformation in the areas of production, consumption, work, and globalisation. But first, we want to shortly describe how we got here. Digital transformations are contingent on the bewildering pace of **digital innovation**, which makes use of increasing amounts of data and intelligent algorithms. The general-purpose information and communication technologies, such as the computer and the internet, have formed the basis of a hectic ecosystem in which subsequent – ever more efficient and user-friendly – inventions and innovations are rapidly accumulating. These innovations are evolving faster than ever, developing in parallel in different areas, and combining and supporting each other.[16] This pattern also characterised previous technological revolutions (the first one, epitomised by the steam engine, and the second one, which brought about electrification), but it occurred at a much slower pace, partly because knowledge circulated more slowly in the pre-digital world.[17] Through the developments and innovations of the years since then, we have seen the astonishing emergence of a new world in which international trade, corporate structure, politics, health, and education – indeed, almost every aspect of life – all are being transformed.

This chapter is about the intricate chain of technological innovations within the third technological revolution, which led up to that historic moment – and beyond, to what has become known as the 'fourth technological revolution'. We aim to map out, in language that we hope the non-technical readers can comprehend, both the mechanisms behind this revolution, and some of the ways our economic life and indeed our societies are being altered beyond past imagination. We will structure this concise description of the technological revolution around the development of the four basic components of every digital product: device (hardware), communication (network), service (software), and content (data and information).[18] You may read it as a kind of an explanation of how the smartphone, the crowning result of the combinatorial innovation of the third technological revolution, and the epitome digital device, came into being. First, we show how the computing machines got smaller and mobile; then, we present how they began to communicate with each other; thirdly, we show how software gave them their enhanced functionality which in turn made them wildly popular among administration, business, and consumers; and lastly, we explain how, by providing access to digitised content, they started to produce huge quantities of data and opened vast new possibilities for human endeavour.

The foundations: the computer and the internet

Device

Today, all **computers** work on a principle similar to that of the steam-driven analytical engine designed (but not built) by the British mathematician Charles Babbage in 1834. It was to be built with a *store* (memory for storing data, with a capacity of 675 bits) and a *mill* (for performing calculations). It would be programmed, he envisaged, using punch cards similar to those used in Jacquard looms; the first programmes for the Babbage machine were written by another mathematician, Ada Lovelace.[19] The analytical machine would do the arduous and time-consuming work of manual calculations.[20] However, Babbage never managed to build his machine: it was just too complicated, too large, and too expensive.

Babbage's invention would have been a steam-powered machine as big as a small locomotive. It required several other key innovations to get from there to the minicomputer, or smartphone, that you hold in your hand. Electrification was one: that allowed the basic design to become smaller and simpler. British programmable electronic machines, built in 1943–1945, were used to decipher German military communications, and were rightly called Colossuses. The first computer designed for commercial purposes – Britain's Ferranti Mark 1 from 1951– weighed half a tonne and required advanced skills to operate. The invention of the **transistor** in 1948 further shrank the size of the computer and replaced the inefficient vacuum tubes that were then used for calculation. A decade later, the integrated circuit appeared, bringing together all a computer's electrical components (transistors, conductors, resistors, diodes) on one silicon chip. However, each computer function was still carried out by a separate chip.

The real breakthrough came with the invention of the **microprocessor**. Intel's first microprocessor in 1971 was roughly the size of a postage stamp, consisted of 2,300 transistors, and carried out 60,000 operations per second. A microprocessor produced just a year later had 3,500 transistors and could do 300,000 operations per second. This roughly confirmed the thesis proposed in 1965 by one of Intel's founders, George Moore. He originally assumed that the number of transistors on a microprocessor would double every one and a half years. A decade later, Moore tweaked his claim: the number of microprocessors would now double every two years. Although Moore's 'law' was more a norm based on observations, it has remained amazingly accurate and still seems to hold in 2020.[21]

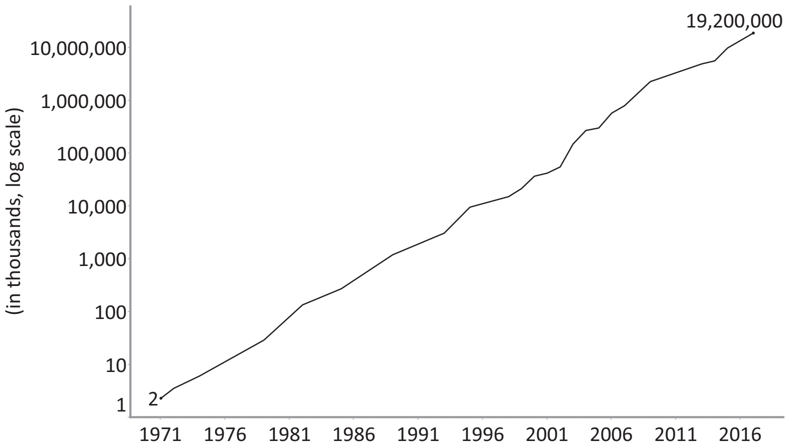

Figure 1.2 Moore's Law – number of transistors per microprocessor (in thousands, logarithmic scale, 1971–2017).

Source: Own work based on Our World in Data. *Moore's Law: Transistors per microprocessor*. https://ourworldindata.org/grapher/transistors-per-microprocessor?time=1971.latest (accessed 23 January 2021).

Miniaturisation has made computers smaller and cheaper. The appearance of the Intel 8008 processor in 1972 contributed to the creation of the first microcomputers (such as France's Micral N, launched in 1973), which in the 1970s would result in the advent of personal computers (PCs, desktop computers). In 1977, Apple Computers, founded by Steve Jobs and Steve Wozniak, began to sell the Apple II, which quickly found its way not only into offices but also into the homes of ordinary Americans. It displayed the talent for consumer-friendly innovation that became the hallmark of Steve Jobs's work. Unlike previous commercially available home computers, it had a colour display, a keyboard, and 48 KB of RAM (memory) – an impressive feature at the time. Then in 1981, the Osborne company launched the first portable computer. It had no battery, but as it only weighed about 10 kg, it could be moved relatively easily from one place to another. The first true laptops appeared in the late 1980s. One, for example, was the Compaq LTE, which led *The New York Times* to write that 'computing on the road becomes an almost effortless extension of computing in an office'.[22] (Interestingly, this laptop, once the lightest in the world, is still used to service the car that was once the fastest in the world, the McLaren F1.)[23] Another seminal moment in the development of personal computers was the first PowerBook, launched by Apple in 1991. This model set a new standard for the design of laptops.

The computers were not the only devices that became rapidly smaller. Miniaturisation also affected the design of phones. The first mobile phone to go on general sale was the Motorola DynaTAC 8000x, on the market in 1984. It

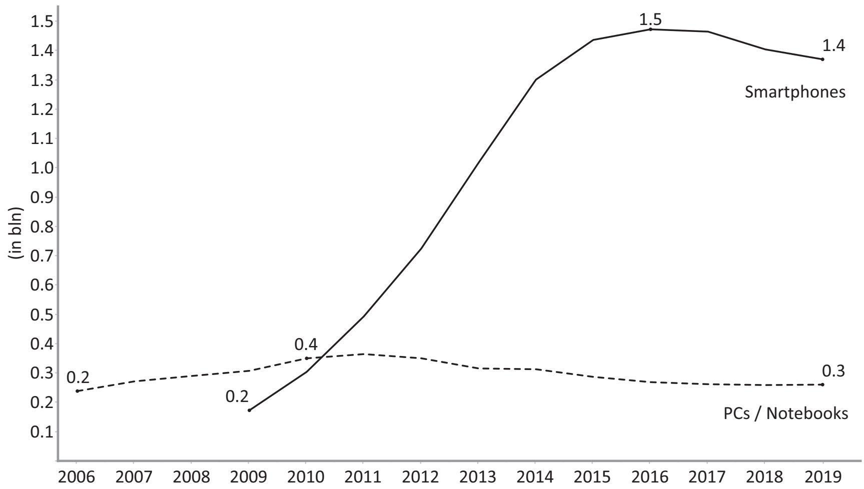

Figure 1.3 PC/Notebook and smartphones shipments (in billion units, worldwide, 2006/2009–2019).

Source: Own work based on IDC. 2020. *Global smartphone shipments from 2009 to 2019 (in million units)*. Chart. In Statista. www.statista.com/statistics/271491/worldwide-shipments-of-smartphones-since-2009/ (accessed 14 December 2020); Gartner. 2020. *Total unit shipments of personal computers (PCs) worldwide from 2006 to 2019 (in million units)*. Chart. In Statista. www.statista.com/statistics/273495/global-shipments-of-personal-computers-since-2006/ (accessed 14 December 2020).

weighed almost a kilo (even its designers called it 'The Brick'), was very expensive (selling for $3,995), and the battery lasted a mere half an hour. And yet it was an instant hit, blowing away competing 'mobile phones', i.e., car phones, which ran off a car's battery. Soon mobile phones became smaller, cheaper, and truly mobile thanks to a smaller and more efficient battery, became a necessity not only for business but also for the ordinary people.

Connection

In parallel, another revolutionary innovation was under way. Computers were increasingly powerful, but they were also huge and unmovable. The people who used them needed a way to exchange data.[24] The answer arrived in the form of the network, invented in the early 1960s by a visionary psychologist and computer scientist from MIT, Joseph C.R. Licklider. In an article entitled *On-line Man-Computer Communication*, written in 1962, 'Lick', as his admirers called him, described how an extensive network of computers exchanging data and programs might function, and might enable long-distance communication and indeed a global reach.[25] He was the right man in the right place. He was already working at the Pentagon's Advanced Research Projects Agency (ARPA) and his ideas promised to solve a problem that had baffled the military. Defence systems were built radially, around one central, main computer. If that computer were to be hit by – say – a pre-emptive nuclear strike, the entire system would be destroyed. Lick's solution was to create a network of devices connected in parallel, communicating via packet switching, i.e., dividing the data stream into smaller parts, and then sending those packets via telecommunications links between network nodes.

In 1969, researchers at the University of California in Los Angeles (UCLA) attempted to log on to a computer at Stanford University, 600 km away, and send data in the form of one word: 'login'. The enthusiastic scientists delivered a running commentary over the phone as the letters gradually appeared on the target screen. After the 'G' appeared, the system froze. Despite this, the event marked the beginning of the internet revolution. Soon, the University of California at Santa Barbara and the University of Utah had also connected to ARPANET (the network built by ARPA). Simultaneously, other institutions were working on their own networks and technological solutions: Britain's National Physics Laboratory (the NPL network), the University of Hawaii (ALOHAnet), Michigan Educational Research Information Triad (the Merit Network), France's CYCLADES, Tymnet and Telenet, and others. Each of the networks worked using different network protocols. However,

> Getting computers to talk to one another – networking – had been hard enough. But getting networks to talk to one another – internetworking – posed a whole new set of difficulties, because the networks spoke alien and incompatible dialects. Trying to move data from one to another was like writing a letter in Mandarin to someone who only knows Hungarian and hoping to be understood.[26]

Further expansion of the network therefore required the creation of a standardised data transmission system. The solution was a protocol model called TCP/IP (Transmission Control Protocol/Internet Protocol), developed in 1973 by Robert Kahn of ARPA and Vinton Cerf from Stanford University. It provided safer, more attack-resistant transmission, and the ability to add new networks without interrupting the operations of those that already existed. Over the next decade, it replaced all previous protocols in ARPANET. In 1981, the US National Foundation for Science supported the development of a network of regional university campuses, connected to ARPANET, which eventually evolved into NSFNET (the National Science Foundation Network). NSFNET served as a skeleton for US networks until the emergence of private internet service providers. It was then that the term 'internet' came into general use as an abbreviation of the term 'internetworking', used to describe how networks used the TCP/IP protocol to work together.

Meanwhile, the commercialisation of another technology incubated by the military contributed to the growing popularity of mobile phones. The analogue telecommunication standard used by Motorola's 'Brick' was not very stable or secure. In 1991 the 2G (i.e., 2nd Generation) standard was introduced.

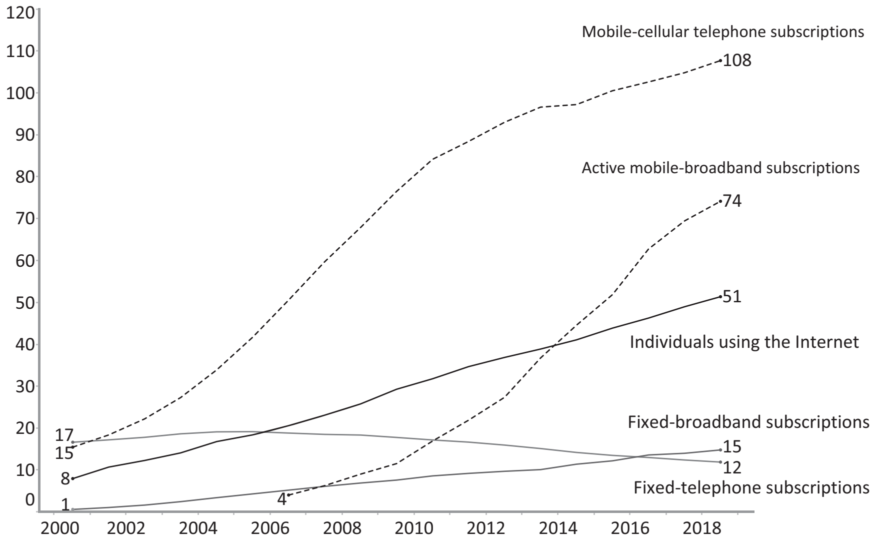

Figure 1.4 Global ICT development indices (number per 100 people, 2000–2019).
Source: Own work based on ITU Global and Regional ICT data.

It offered a completely digital, encrypted signal, enabling the sending of short text messages (SMS, for 'Short Message Service'). The digital signal improved connections, provided better coverage over a larger area and reduced battery use.[27] This accelerated both demand for mobile phones and also their technological development. The 3G network, rolled out in 1998, enabled data transmission and access to the internet. Since 2009, 4G networks have enabled data transfer speeds that are ten times faster than the 3G standard, and often faster than traditional landline internet connections. In 2020 the implementation of a new mobile connection standard – **5G** – entered a decisive phase. It provides data transmission speeds of up to ten times faster than before, which minimises latency (time of response) and battery consumption (by as much as 90%). Thanks to 5G, individual users can download games faster and watch films in better quality. Above all, it will make it possible to connect a much larger number of devices, paving the way for the Internet of Things (to which we will come later in this book).

Service

The function of the first computers was simply to compute, or to perform quickly and efficiently the tedious calculations previously executed by humans (mainly by women).[28] This explains why governments, and particularly the military, found computer technology so valuable. Not only were the Colossuses of the 1940s used for decoding German messages and winning the strategic struggle at sea. The need to calculate the data for building a thermonuclear bomb led to the next breakthrough invention, when John von Neumann, a mathematician and early computer scientist, developed a new rule for computer architecture. Previously, computers were programmed externally with hundreds of thousands of punch cards.[29] The new ones were equipped with previously inscribed programs and were thus much more user-friendly.[30] In 1955, there were only 250 computers in the world.[31] But a decade later there were 20,000 and they were being used by armies, universities, public institutions, and some big corporations to support routine administrative processes. As Martin Campbell-Kelly, an expert on the history of computing, points out, these tasks might include:

> payroll, billing, and report generation – all of which tasks had already been at least partially mechanized through the use of typewriters, tabulating machines, and mechanical calculators. In many large corporations this work had already been delegated to specialist data-processing departments. Many of the computers IBM introduced in the late 1950s were designed specifically to appeal to such departments and were in fact marketed as tools for 'electronic data processing', or EDP. Over the course of the 1960s, EDP would drive the majority of computer use in the corporation, despite the fact that many computer experts saw it as the least interesting application of computer technology.[32]

Still, the size and the cost of the computers placed them beyond the reach of small and medium-sized businesses. A decade later, personal computers had become smaller and more affordable but were still cumbersome to use. A popular build-it-yourself computer called the Altair did not have a keyboard or a screen. It was operated by switches, and the results of its calculations appeared in the form of light-emitting diodes (LEDs) that lit up. The Altair became easier to use when the company that produced it hired two Harvard students – Paul Allen and Bill Gates – to adapt a programming language to its requirements. Gates and Allen used the money they thus earned to establish their own company, which they called Micro-Soft. In 1981, their company introduced DOS (i.e., Disk Operating System), which enjoyed instant popularity and would later become the basis for Windows. In parallel, Steve Jobs and Steve Wozniak were encouraging programmers to create applications for Apple. One of the most useful turned out to be the VisiCalc spreadsheet, developed in 1978: it freed the accountants from tedious and time-consuming work on paper ledgers.[33] It became one of the first 'killer apps', which convinced millions of companies to invest in computers.

But why would anyone want a computer in their home, even if equipped with electronic spreadsheets?[34] The first computers for personal use were bought mainly by enthusiastic hobbyists, often to play games on. The real explosion in computer popularity came only with the development of the internet and the

World Wide Web. Not at once, though. The first British internet service company, Demon Internet, had nearly 3,000 customers in 1993 and according to its founder Cliff Stanford:

> The question we always got was: 'OK, I'm connected – what do I do now?' It was one of the most common questions on our support line. We would answer with 'Well, what do you want to do? Do you want to send an email?' 'Well, I don't know anyone with an email address.' People got connected, but they didn't know what was meant to happen next.[35]

Those already connected mainly used the oldest internet application, i.e., e-mail, which had existed since the early 1970s. A fundamental problem with the early internet was how to search for information online. At the end of the 1980s, archiving programs began to appear: one of the first was Archie, created by Alan Emtage and Peter Deutsch, two students at McGill University in Montreal. From time to time, Archie would search all the available sites, create a list of files posted on them, and then build an index. Using it, however, was quite complicated.

In 1989 Tim Berners-Lee, a British computer scientist, and other employees at the European Laboratory for Particle Physics at CERN in Switzerland invented a protocol that made publishing, searching for, and using information online much easier. It became the basis for the **World Wide Web**, 'a wide-area hypermedia information retrieval initiative aiming to give universal access to a large universe of documents', as Berners-Lee once described it.[36] In 1993, Berners-Lee put the World Wide Web in the public domain, thus making it available to everyone. The secret to the World Wide Web's success was a graphic **browser,** a piece of software that could retrieve on command a web page from a particular site – and display both text and images on the same page, which greatly simplified surfing (i.e., navigating from one online page to another). Now everyone could search for digital content quickly and easily.

However, some sort of system was still needed for creating a hierarchy of the content that might interest a particular user. One, based on a ranking system, was proposed by two students at Stanford University, Larry Page and Sergey Brin. Thus was the Google search engine born.[37]

Content

Digitisation means that analogue data is encoded in a digital format, which makes it machine-readable. To quote online Britannica, nota bene the digitised version of the voluminous paper encyclopaedia, 'The versatility of modern information systems stems from their ability to represent information electronically as digital signals and to manipulate it automatically at exceedingly high speeds'[38]. The first instance of binary – i.e., encoded in zero, one, two symbols system – digitisation were punch cards invented by Ada Lovelace for the Babbage machine, which were to tell the machine what operations should be executed and in what order. Text was first digitised in the 1960s to speed up the time and reduce the cost of publication of two professional abstracting journals.[39] The first digitised photograph was made in 1957 with the help of a computer whose main function was to carry thermonuclear weapons calculations – uncannily enough, it was a picture of a baby boy.[40]

Digitisation gained momentum in the 1980s when private companies and public institutions began linking up their desktop computers via local area networks (LANs). These Ethernet networks enabled data to be exchanged solely in digital form, which produced a host of benefits, the most obvious of which were speed and savings – though, interestingly, it was only in 1996 that it became less expensive to archive material digitally than on paper.[41] Organisations as a whole gained access to new data and information that they could use to improve efficiency. Once the process of sharing information was digitised, there was a radical increase in the volume of data generated, stored, sent, and consumed.[42] Soon companies and public institutions started to use the internet to contact their partners and customers, thus beginning a transformation of these relationships.

Meanwhile, the content of the internet grew rapidly. In 1993 there were no more than 200 websites, but by 1998 there were already around 2.4 million.[43] But the internet soon became more than an index of static websites. As of autumn 2020, there are perhaps 5.47 billion web sites[44] – but there is also a vast array of applications, which enable people to chat, participate in forums, and buy online. One result has been the emergence of a vast online marketplace, discussed later in this book and dominated by Amazon, founded with extraordinary prescience in 1995.

By the middle of the first decade of the 21st century, the internet had evolved into a space full of dynamic content, created by its users, such as amateur movies published on YouTube (2005). This process has intensified following the emergence of social media, such as Facebook (2004) and Twitter (2006). Personal computers, tablets, and then smartphones became the tools for enjoying digital goods – digitised books, music, and movies. And early on, consumers of digital content and services started to produce a highly valuable resource: data.

The inflexion point: smartphones and sensors

There were **smartphones** before iPhone: one of the first devices of this type, the IBM Simon, had been launched in 1994,[45] but the actual term was first used to sell the lightweight and multi-functional Ericsson R380, operating on the Symbian OS. However, it took the arrival of the iPhone to reveal the truly subversive nature of the technology. The iPhone was an example of ingenious miniaturisation that combined functions which, up until that point, were usually offered on separate devices.[46] When, in January 2007, the late Steve Jobs, then the boss of Apple, unveiled the first iPhone, he announced: 'Every once in a while, a revolutionary product comes along that changes everything.' The iPhone, he pointed out, offered three gadgets in one: a 'widescreen iPod with

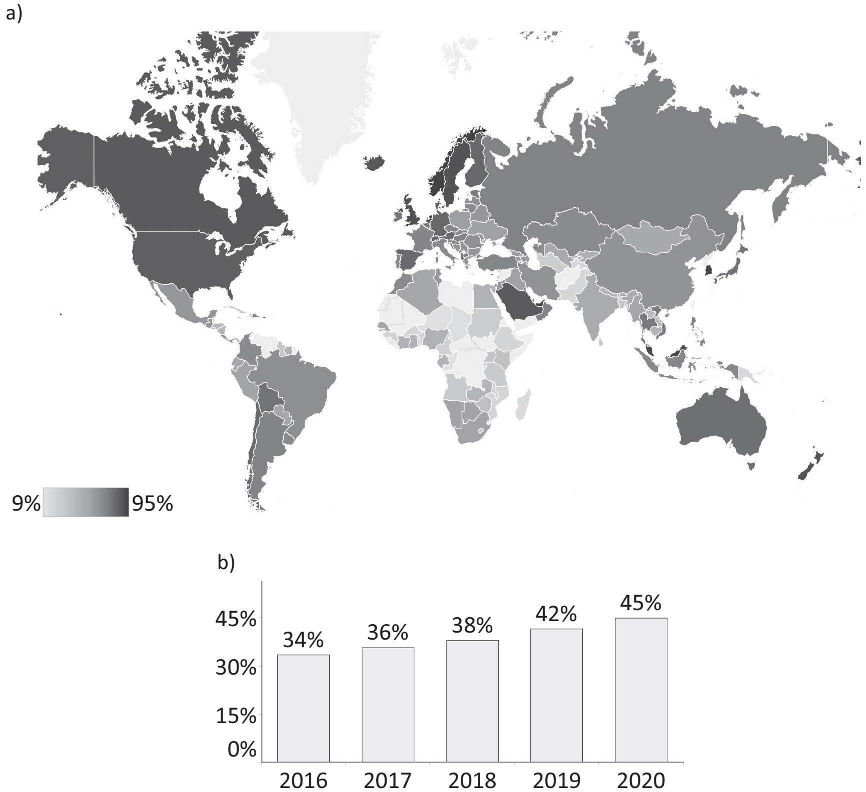

Figure 1.5 Smartphone penetration rate: (a) by country (2020); (b) worldwide (2016–2020).

Source: Own work based on Statista. 2020. *Ranking of the smartphone penetration by country 2020*. Chart. In Statista. www.statista.com/forecasts/1143893/smartphone-penetration-by-country (accessed 14 December 2020); Statista. 2019. *Global smartphone penetration rate as share of population from 2016 to 2020*. Chart. In Statista. www.statista.com/statistics/203734/global-smartphone-penetration-per-capita-since-2005/ (accessed 14 December 2020).

touch controls', a 'revolutionary mobile phone', and a 'breakthrough Internet communicator'.[47] The iPhone contained preinstalled games, a still camera, and a video camera, but an ordinary Nokia phone could boast these features too. Its competitive edge lay in its touchscreen and touch keyboard, integrated web browser and durable battery (the rival IBM Simon was pulled from the market after a few months because its battery only lasted an hour). Soon similar solutions were introduced by the rival technological companies, Google and Microsoft. In 2020 3.5 billion people – 45% of the world population – owned a smartphone.[48]

The smartphone crowned the cumulative processes of innovation which had been building up in Information and Communication Technologies (ICT), and became the digital product marking the birth of the fourth technological revolution. The average smartphone combines the function of a mobile telephone with a portable computer that can be constantly connected to the internet. But this was not the crux of the disruption it brought about. Each smartphone can deploy a vast range of life-simplifying applications (or apps), which allow users to do everything from tracking their bank balance to measuring their heart rate. As of 2020, there were more than 2.87 million apps in the Google Play store and 1.96 million in AppStore.[49] Google's Android – the system underpinning the operation of 74% of all the smartphones in the world – allows innovators freely to gain access to the operating system (OS) and to the data that individual users constantly generate.[50] The application developers and individual users are locked in a symbiotic cycle: the developers feed off the data produced by the users, providing them in exchange with applications that increase the functionality of the main device. The operating system, as an intermediary – or platform – between individual users and application developers, must strive to attract as many members of both these groups as possible. The OS provider also benefits from the rising inflow of data, which it uses for optimising the system and selling to advertisers. Smartphones routinely use computational resources in the cloud, which are supported by artificial intelligence.

Another key device which evolved during the third technological revolution is misleadingly modest in appearance. An **intelligent sensor** is a combination of a sensor and a microprocessor. It not only gathers information on specific parameters of the physical environment but primarily it uses its own computational resources to analyse the information and transmit data when it detects a specific change in the environment.[51] So far most intelligent sensors have been used in industry (to measure pressure, temperature, or proximity, for example). They monitor the work of machines in real-time, which allows failures to be prevented early. They are a key factor in the automation of transport and deliveries, the optimisation of equipment and vehicle movements in factories, and they are vital in warehouse management. They also help to regulate energy consumption by matching consumption with needs.

The increasing use of sensors revolutionised another innovation of the third technological revolution: the **robot**, i.e., a programmable machine capable of carrying out autonomous tasks and manipulating objects. In 1962, the first 'robotic arm' was installed at a General Motors factory; it could perform one type of repetitive operation (in this case diecasting).[52] In the late 1960s, scientists at Stanford University built an arm that could move in six axes; by the 1980s, however, robots were still far from being mobile devices and were unable to sense their surroundings. This changed when smaller and cheaper sensors were coupled with computing power supported by artificial intelligence, and with advanced actuators (components that carry out movements).[53] In 2019, 2.7 million industrial robots were working worldwide, 1.1 million more than in 2015.[54] Most of them worked in the automotive, electrical/electronic, metal, and machinery sectors.[55] The development of multifunctional collaborative robots (or 'cobots') that will support workers in industrial and food production, health care, and packing products has allowed dramatic increases in productivity.[56] Efforts are also being made to create robots that cooperate in the cloud (*cloud robotics*), i.e., ones able to share computing power and perform coordinated actions.[57]

In 2006, there were 2 billion intelligent sensors in the world; in 2020, there were probably as many as 200 billion.[58] Their use accelerated considerably as their decreasing size and price (from $1.3 in 2004 to below 60 cents in 2014)[59] were coupled with the growing possibility of connecting them with other devices. This depended heavily on the power of the network: with the 4G standard, 110,000 devices could be connected per square kilometre, but the 5G standard allows over a million.[60] This huge rise in network capacity has helped to foster the development of the **Internet of Things**, a network of connections between physical objects equipped with sensors, which allow data to flow between them. Objects belonging to the network can digitally identify and communicate with other devices. It allows for the development of track-and-trace systems in logistics; in manufacturing, it gives rise to smart factories.

Intelligent sensors are widely used in things people wear, both in the form of devices built into clothes and of a variety of accessories such as watches,

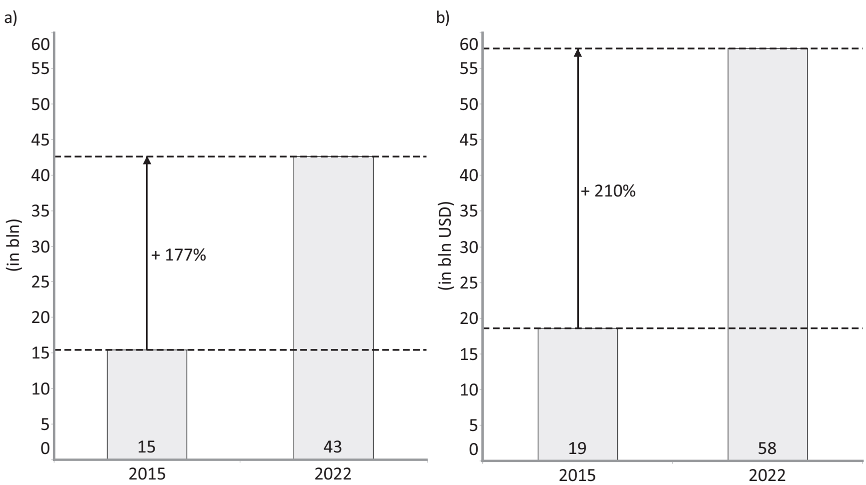

Figure 1.6 (a) Number of interconnected IoT devices (in billion units, worldwide, 2015 and 2022*); (b) global smart sensors market size (in billion USD, 2015 and 2022*).

Source: Own work based on Forbes. 2016. *Internet of Things (IoT) connected devices installed base worldwide from 2015 to 2025 (in billions)*. Chart. In Statista. www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/ (accessed 14 December 2020); Rix, N. 2015. *Global smart sensor market size in 2015 and 2022 (in billion U.S. dollars)*. Chart. In Statista. www.statista.com/statistics/740558/global-smart-sensor-market-size/ (accessed 14 December 2020); *prediction.

bracelets, and rings. They are used primarily to monitor health and physical activity, mainly by those trying to lead a healthy lifestyle, but they are increasingly used in healthcare. Sensors embedded in special bracelets can measure basic vital signs and alert a healthcare specialist in the event of irregularities. When I am writing these words on my PC, my smartband is sending data about my pulse to my smartphone, which at the same time streams some lulling Mozart into my wireless headphones. I experience the functioning of a 'second economy' in which objects are 'talking to each other' unbeknownst to humans.[61] According to one prediction, in 2021, people will be wearing more than 900 million devices equipped with sensors.[62]

The development of the IoT is also a key factor in the development of smart cities, with intelligent buildings, intelligent apartments, and intelligent transport (we will write more about those in Chapter 5). Saturating the environment with devices that record all manner of activities, however, raises a whole host of concerns about data security and the protection of users' privacy. Another challenge for building an intelligent ecosystem is also to ensure a high level of interoperability, i.e., the ability of devices to work effectively with one another.

The breakthrough: data and algorithms

The Big Bang of data

In just one global minute while this book was being prepared, 188 million e-mails were sent (not only by people but also spambots), 350,000 tweets were tweeted, Google's search engine was queried 3.8 million times, and Skype was used 180,000

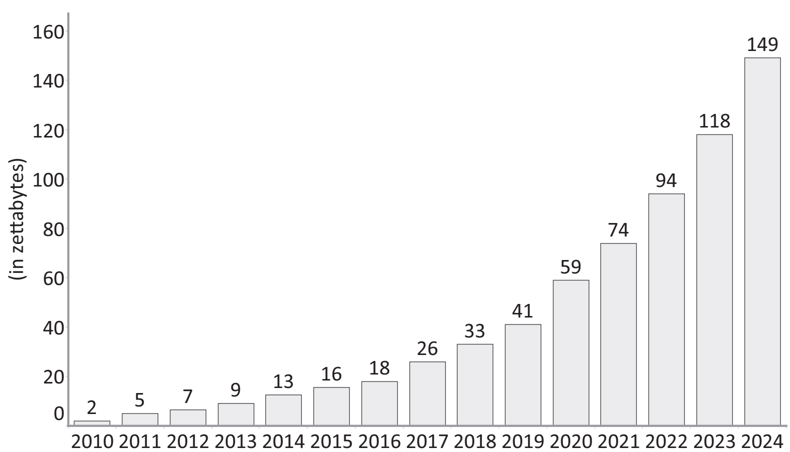

Figure 1.7 Volume of data as an effect of digitalisation (in zettabytes, 2010–2024).

Source: Own work based on IDC, Statista. 2020. *Volume of data/information created, captured, copied, and consumed worldwide from 2010 to 2024 (in zettabytes)*. Chart. In Statista. www.statista.com/statistics/871513/worldwide-data-created/ (accessed 14 December 2020).

times. (As you will see if you go to the linked source, these data change every second.)[63] Data is pouring from IT systems: it is being generated by the individual business, and institutional users of the internet and mobile applications, it is being reclaimed from the archives of public institutions and companies, and it is being gathered by an increasing number of sensors located not just in devices, but also in personal accessories and in private and public spaces. In 2015, IBM claimed that in just the previous two years (2013–2015) 90% of all data ever generated had been produced.[64] Data volumes are increasing exponentially, doubling every three years. This should come as no surprise, of course: if you go to the Internet Live Stats site listed below, you will see the reasons.

The increasing application of devices equipped with sensors to track changes in the surrounding environment has accelerated the data flow. For example, an average car can be equipped with up to 200 sensors that generate 1 terabyte of data per day.[65] Cautious estimates suggest that 26 billion different devices (less cautious ones go up to 50 billion) *already* make up the Internet of Things.[66] The world's 6.1 billion smartphones also contain sensors, mainly to detect movement. As a result, by 2020 the volume of all the data generated approached the unimaginable number of 59 zettabytes (59 times 10^{21} bytes).[67]

A large amount of the data currently being produced has specific properties: it is highly diverse, complex, and usually poorly structured. Analogue data is different, in an important way. Before being etched onto a clay tablet or noted down in an accounting book, numbers or letters were ordered in a certain way so that another user would know how to read them. Usually, digital data collected by public institutions, corporations, and NGOs is initially similarly ordered. In contrast, data generated by social media sites, server logins, online shopping, geolocation systems, and sensor readings are poorly structured. In 1997, two NASA researchers, Michael Cox and David Ellsworth, proposed calling this type of data big data. Two years later, Doug Laney, an analyst at Gartner, a consulting company, was observing the problems his clients had with data from various sources, its structure and different formats, and declared that big data was characterised by high *volume*, the *velocity* at which it was produced, and its variety.[68] Over the next two decades, this list grew to 10 Vs: in addition to those already mentioned, one can focus on its multifacetedness and the inconsistencies within big data (its *variability*), its relatively low *veracity*, as well as its accuracy (*validity*), its *vulnerability* to cyber attacks,[69] the short-term nature of its usefulness as regards the profitability of archiving such large data sets (*volatility*), challenges when it comes to *visualisation* and its business *value*.[70]

'Contamination' in large data sets (due to their diverse nature and lack of structure), and the need to resort to innovative methods to analyse the sets, has created a need for a new type of skill in **data science**, which is more than just data analysis.[71] It is somewhat reminiscent of the process of refining so data becomes information that is useful for business (and increasingly the public sector as well). It is cleaning and organising the data that takes up the most time, on average 60%, while data mining for patterns and improving algorithms accounts for only 13%.[72] Big data definitions frequently draw attention to the fact that non-standard methods must be used to collect, process, analyse, and visualise it, and some definitions conceive of big data more as technologies and technological structures.[73] To quote OECD's concise definition: 'Big Data is commonly understood as the use of large scale computing power and technologically advanced software in order to collect, process and analyse data characterised by a large volume, velocity, variety and value.'[74] In this book we will refrain from using the widely-used ambiguous concept of big data, which conflates the notion of data as a raw analytical substrate with methods used to analyse it. Instead we will focus on just the former – the notion of data as a product of digitalisation and a substrate of datafication (we will explain shortly) – and emphasise volume as the most important trait of data nowadays by using the notion of **abundant data**.

The sheer volume of online data has led to the development of ways that allow companies to use software that is not installed on their servers. The result has been the evolution of various computational resources – servers, databases, software, archiving – which are not located on a local computer, but are stored in huge data centres.[75] These **cloud solutions** first appeared in the late 1990s and allowed companies to use software that was not installed on their servers, thus lowering the cost of infrastructural and software investments necessary for embarking on digital transformation. Cloud services may give access to infrastructure (disk space and computing power), platform or software, communication solutions or platforms (infrastructure which integrates programs and applications that operate in various operational environments). Cloud services are not just for companies: they also widely available for individuals. In

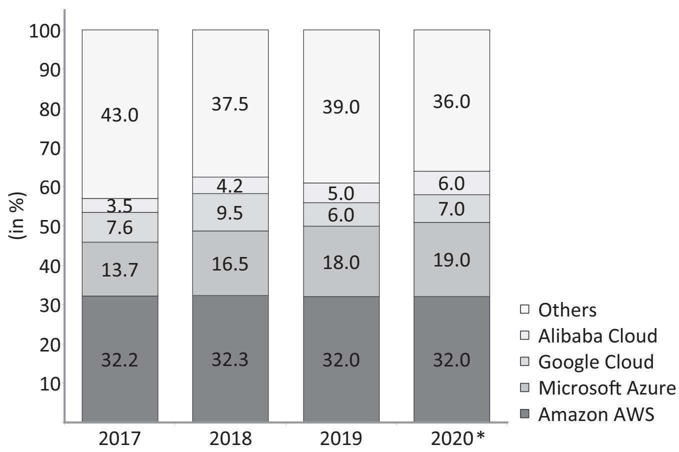

Figure 1.8 Cloud infrastructure services vendor market share (in %, worldwide, 2017–2020).

Source: Own work based on Canalys, Statista. 2020. *Cloud infrastructure services vendor market share worldwide from 4th quarter 2017 to 3rd quarter 2020.* Chart. In Statista. www.statista.com/statistics/967365/worldwide-cloud-infrastructure-services-market-share-vendor/ (accessed 28 January 2021); *–Q3 2020.

2018, six years after its launch, Google Drive had a billion users[76]. However, the largest share of the overall cloud services market in 2020 is claimed by Amazon (Amazon Web Services).Its one-third share is greater than that of its three biggest competitors combined: Microsoft, IBM, and Google.[77] Cloud services are also being developed by Chinese technology companies such as Alibaba Cloud, and Tencent.[78] As of now, they trail behind the US-based cloud providers, but still they control 70% of the Chinese market and plan to invest heavily to gain ground in other Asian countries.[79]

Intelligent algorithms

The sheer volume of data is not enough to make it useful. To squeeze value out of it you need powerful analytics. Traditional data analysis based on statistical tools and simple algorithms that allow for automation is enough to spot patterns in data and to formulate predictions. But real analytical efficiency and insight require a more sophisticated technology: **artificial intelligence**.[80]

Back in the 1950s, when the research on 'thinking machines' was initiated, there were two approaches to the construction of 'artificial intelligence' – symbolic and statistical.[81] The first approach held that artificial intelligence could be created by constructing a strict set of rules that it would follow when solving problems. The 'symbolists' managed to build 'Logik', a program that used the principles of formal logic to automatically prove mathematical theorems. It is no wonder then that the 1960s were dominated by great optimism regarding the possibility of creating a machine equally – or even more – intelligent than a human. Yet, machines had failed to learn to recognise speech, classify images, or translate from one language into another.[82]

The followers of the second approach posited that a computer 'fed' with large amounts of data would, on its own, learn to spot trends via constant repetition, experimentation, and feedback. But they lacked properly large and digitised datasets and the computational resources of the machines they worked with were too weak. The hopes revived once computers started to offer greater calculating power and internet users generated large data sets. The statisticians finally got the opportunity to show off. They started to create algorithms that could analyse data, learn from it thanks to advanced statistical techniques, and make decisions based on the results.[83] Thus **machine learning** was born. Meanwhile, the researchers returned to the idea of using a series of algorithms somewhat reminiscent of the structure of a human brain – a so-called artificial neural networks. The idea was first articulated back in the 1950s by Frank Rosenblatt.[84] His Perceptron was hailed as the first 'learning machine', but it failed to deal with basic classifications because it operated on only one layer of neural networks. The growth of computational power allowed for building multi-layer artificial neural networks that can recognise relationships between vast amounts of data. Each layer allows for deepening the insight as the information travels through the layers, and that is why this subset of machine learning is called **deep learning**.

Machine and deep learning can be *supervised*, *unsupervised*, and *reinforced*. In the first, the program is given data (that has already been labelled by humans or other machines), which establishes the subject to be learnt; in the second case, there are no labels, and the program just finds patterns in data according to rules. In the third version, artificial intelligence independently tests various solutions and selects the best to achieve a set goal. The potential of reinforced learning was shown in 2016, when AlphaGo, a program developed by Google's DeepMind team, defeated a South Korean Go champion (Go is an ancient Chinese game that is much more complex than chess). The program, fed with data on games previously played by humans, learned to play at a master's level in just three days, playing a million rounds with itself. But the real breakthrough was heralded by AlphaGo Zero.[85] The self-learning neural network was given no previous data – it independently tested various solutions and selected the best to achieve a set goal. Just like Alpha Go in three days achieved the master level of a human, AlphaGo Zero in 40 days learned how to beat all its predecessors. Such impressive **reinforced learning** involves huge amounts of computational power, and the cost of training deep neural networks are exorbitant.[86] Widespread rolling out of this technology requires further advances in computing and the design of the algorithms themselves.

It is worth noting that today's artificial intelligence in no way resembles the type which science-fiction films would have us imagine. Successes in the field of building **strong (deep) AI**, i.e., a machine whose intellectual abilities are indistinguishable from human intellectual abilities, are so modest that some experts doubt whether it is possible at all.[87] No matter: the economic, social, and political implications of rolling out of the **applied** or **narrow AI,** which relies on advanced information processing, are revolutionary enough. Kai-Fu Lee, author of the book *AI Superpowers: China, Silicon Valley, and the New World Order* (2018),[88] and one of the foremost experts in artificial intelligence, who was also the creator of one of the first speech recognition programs, claims that the development of artificial intelligence will proceed in four waves:

- **Internet AI** is already widely used today. It consists of user-profiling recommendation algorithms that learn from the masses of data about what a particular person does on the web. This type of AI is responsible for correctly tailoring ads, recommending products (Amazon, Alibaba), proposing new content (YouTube), optimising user involvement through natural language processing and computer image processing, and labelling users.
- **Business AI** is increasingly being used. Algorithms can bring together threads in historical data that a human could never have associated with each other, and discover hidden correlations between data and events, something which is used in the banking and insurance sectors, and which is beginning to be used in the health service and the judicial system. This allows organisations to optimise expenses, minimise losses, and better tailor loans and insurance policies.

- **Perceptive AI** is on the way, thanks to which the virtual world will merge with the real world. Ubiquitous sensors of the Internet of Things will allow artificial intelligence to gain senses, accelerating AI's evolution. This kind of artificial intelligence 'will bring the convenience and abundance of the online world to offline reality' and will pave the way for smart factories, homes, and shops, as well as intelligent consumption.
- **Autonomous AI** will be able to feel and respond to the real and virtual worlds surrounding it, move and act productively, and optimise its own actions. An example of this will be, for instance, drones, which thanks to computer image processing will be able to recognise and destroy weeds growing amongst crops. Alternatively, heat-resistant drones will extinguish fires on their own, or – most incredibly of all-humanoid robots will be used in everyday life and the army.

In simple terms, artificial intelligence is tantamount to **intelligent algorithms**, most often based on supervised learning, that allow for faster and cheaper searching, analysing, matching, recommending, and predicting. Ajaj Agrawal, Joshua Gans, and Avi Goldfarb in aptly argue that the intelligence they offer is rather of 'Central Intelligence Agency' kind, not the 'human intelligence' kind.[89] But it is more than enough to revolutionise the operational and business models of the companies (and the operations of other kinds of institutions). The IT companies from nine countries surveyed by Deloitte in 2020 claimed that the AI technologies allow for 'making processes more efficient' and enhance

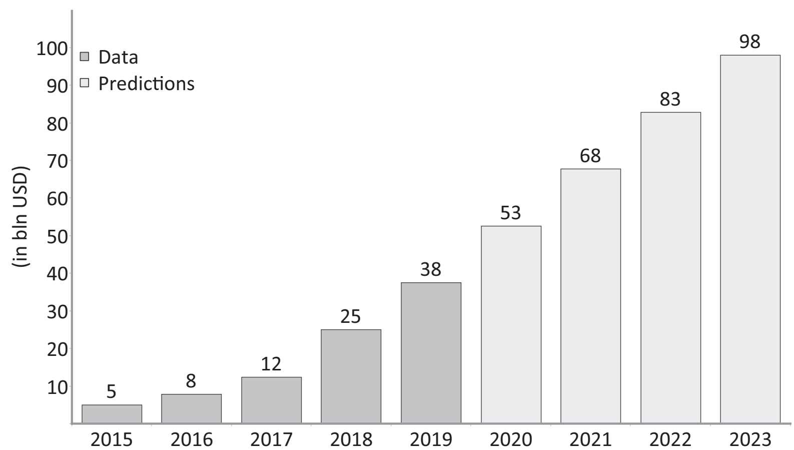

Figure 1.9 Global AI market size (in billion USD, 2015–2023).

Source: Own work based on Statista. 2020. *Market size and revenue comparison for artificial intelligence worldwide from 2015 to 2025 (in billion U.S. dollars).* Chart. In Statista. www.statista.com/statistics/941835/artificial-intelligence-market-size-revenue-comparisons/ (accessed 14 December 2020).

existing products and services. And most importantly, rolling out AI to automate, optimise and enhance the tasks of human workers no longer requires building an expensive inhouse software infrastructure – it can be bought in the cloud. Only one in five surveyed companies invested more in building than buying the AI potential.[90]

Further democratisation of AI is provided by **automated machine learning** (AutoML): a company may buy a ready model of machine learning, which was already trained (it usually takes weeks and requires in-house data science expertise) and its outcomes were analysed.[91] '**AI for hire**' is becoming the flagship product of the biggest technological companies. There is an unprecedented symbiosis going on here: it was only the emergence of huge data sets that enabled the application of artificial intelligence. No wonder that the companies to pioneer intensive investment in this area have been corporations such as Amazon, Google, and Facebook, which have access to vast amounts of client-generated data.[92] Amazon emphasises that without machine learning it 'couldn't grow its business, improve its customer experience and selection, and optimise its logistic speed and quality'.[93] In 2020 the 57% of its operating income was generated by Amazon Web Services, which offer, among others, the cloud-based AI services such as Amazon Lex (which enables building automated conversational interfaces into applications) or Amazon Rekognition (that allows for image analysis).[94] Google declares that machine and deep learning are a priority for the company because they allow it to apply 'AI to products and to new domains, and developing tools to ensure that everyone can access AI'.[95] On its own website AI Google sports stories on how AI may help to advance social good. Facebook AI Research, meanwhile, is headed by Yann LeCunn, a French computer scientist who is one of the fathers of deep learning. His team say they are committed 'to advancing the field of machine intelligence and are creating new technologies to give people better ways to communicate'.[96] One of the instances of their work is GrokNet, a system that develops image recognition for commercial purposes.[97] Access to operational AI becomes easier and cheaper even for small and medium companies, forming the necessary conditions for digital transformation.

The properties of the digital economy

Now it is the time to get back to the properties of the digital economy and brave another approximation at its definition. Digital economy builds on the basis of the internet economy – it takes computerisation, automation, and internet connectedness to the next level of **ubiquitous computing via digital devices**, **intelligent automation everywhere**, and **platformisation**. It is also characterised by the extraordinary pace of innovation. As we have shown earlier in this chapter, digital devices such as smartphones consist of four layers: device (hardware), connection (network), service (software), and content (data). Innovations may appear on each layer independently, and they frequently enhance each other, producing yet another innovation. The truly transformative innovations now are less often in the device or network, but in the way software and data are used. As noted by Hal Varian, Google's chief economist,

> Now what we see is a period where you have Internet components, where you have software, protocols, languages, and capabilities to combine these component parts in ways that create totally new innovations. The great thing about the current period is that component parts are all bits. That means you never run out of them. You can reproduce them, you can duplicate them, you can spread them around the world, and you can have thousands and tens of thousands of innovators combining or recombining the same component parts to create new innovation. So there's no shortage. There are no inventory delays. It's a situation where the components are available for everyone, and so we get this tremendous burst of innovation that we're seeing.[98]

The innovations in software and content contribute to the development of new organisational and business models. As we will show in the next chapter, the innovative business model of platform revolves around the use of an ingenious algorithm and abundant data. More and more companies deftly use the potential of data and networks to optimise their functioning by adopting the 'data first, AI-first' rule. Digital models and solutions now permeate almost every sector of the economy in most countries, from service industries to manufacturing, and agriculture. As a result, we are seeing a change in the functioning of the market for production factors, the market for goods and services, the financial system, enterprises, governments, and households.[99] Consumption, production, and work are all being revolutionised by multiple digital transformations propelled by datafication and datafied networks.

Datafication

Datafication is a growing tendency to create digital representations of ever more areas of the real world in order to derive value from information obtained.[100] It involves extracting useful insights from data about a phenomenon or a process with the support of analytical tools. The word refers to the practical results of the virtuous circle between the growing amount of data and the growing application of intelligent algorithms. For example, I have recently datafied my sleep by wearing a smartband at night that measures my sleep efficiency. In the morning, a smartphone application tells me how well I slept. Now I know that I sleep better than 60% of users but wake too many times during the night. Perhaps I will put this information to use and quit drinking coffee after 8 pm. Individuals have access to more and more data, which they can use to make life-related, professional, and consumer decisions.

But the real beneficiaries of datafication are elsewhere. Companies – from corporations to small and medium-sized enterprises – have never before faced such a spate of data, data which can be used to increase productivity,

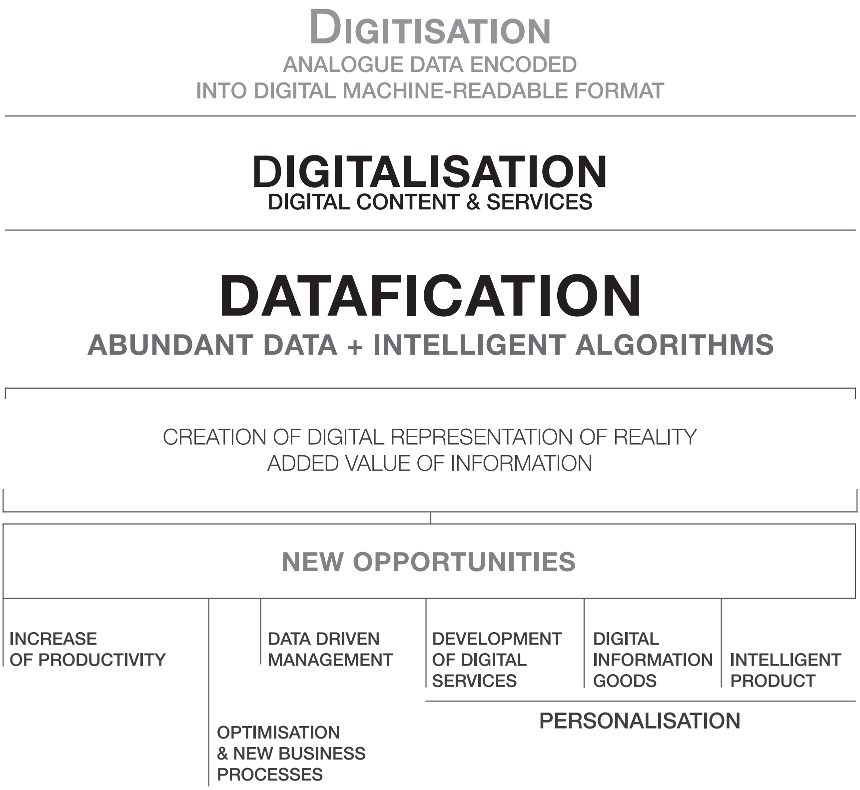

Figure 1.10 The mechanisms of datafication.
Source: Own elaboration.

optimise business processes, improve management, make more accurate real-time decisions, personalise products, adjust offerings, and expand into new markets.[101] This data can be bought, but it is also generated by those using a company's products and services and churned out during production in industrial facilities kitted out with the Internet of Things. As Erik Brynjolfsson, director of the MIT Initiative on the Digital Economy, notes: 'More and more important assets in the economy are composed of bits instead of atoms', and therefore data should be treated as a completely new type of capital:

> Computing hardware used to be a capital asset, while data wasn't thought of as an asset in the same way. Now, hardware is becoming a service people buy in real time, and the lasting asset is the data.[102]

It had been said, with only slight exaggeration, that data have become for the modern economy what coal and steel were initially for the industrialised economy, followed by oil in the 20th century. Data not only affect the efficiency of doing business; they also determine the development of new business models, solutions and economic relations.[103] Treated as capital, data have a host of interesting properties:

- They are non-fungible – a single data set cannot be replaced by another, because it contains completely different information. Products such as barrels of oil are completely replaceable.
- They have a non-rivalrous nature – a single data set can be used simultaneously by many algorithms or applications and analysed without losing its basic value. Meanwhile, money or a piece of equipment/infrastructure can be used by only one actor at a time.
- The value of a data set is equal to the information it contains, and so this value can be assessed only after obtaining the information. However, the information acquired can be easily replicated. By contrast, the value of a durable good can be attained only by taking possession of it; merely having information about it is useless.[104]

This huge resource is not always properly appreciated, priced, or even noticed. Tom Godwin's witticism has gone down in legend; in 2015 he stated that: 'Uber, the world's largest taxi company, owns no vehicles. Facebook, the world's most popular media owner, creates no content. Alibaba, the most valuable retailer, has no inventory. And Airbnb, the world's largest accommodation provider, owns no real estate. Something interesting is happening.'[105] He was clearly right. Companies like Uber, Alibaba, and Airbnb do not have tangible resources, but they have gigantic resources of data and the technology to derive economic value from it. According to researchers from MIT, many companies 'are light on physical assets but heavy on data assets'.[106] Specifically, standard economic indicators find it hard to capture the specificity of the new business models being developed by tech firms and platforms. A financial audit carried out at Facebook for 2011 showed the company had $6.3 billion of resources: computer hardware, office equipment, and other items. The value of the data in its possession was deemed by the auditors to be worth precisely zilch.[107] This failure of standard economic indicators to deal with the new reality shows how new technologies and the deluge of data are driving a radical change in economies.

The ability to derive value from data is increasingly determining firms' competitive position in the market through the development of intelligent services and products (personalisation), automation of business processes, new ways of building networked relationships, and data-driven management (new business models).

At the most basic level, more efficient and faster analysis of large data sets allows organisations to optimise decision-making processes. Intelligent automation makes faster, more accurate, and cheaper analysis available to an increasing number of companies, including those that cannot afford to employ a team of researchers. Better still, the analysis is as easy as using a spreadsheet. A company may, for example, go to the Data Robot platform, which cleans up and reformats inputted data, and then runs it through dozens of algorithms. It can find a more accurate solution than those built on standard statistical models, with no prior preparation. It works 'Out of the box, with the push of one button; that's pretty impressive', as one user puts it.[108] In commerce, where data can be obtained not only from the marketing, sales and customer service departments but also from pricing reports and social media, the ability to process it allows for a more complete view of buyer behaviour and of the competition. Personal data, obtained by purveyors of online services, is used to create more effective marketing campaigns that reach the right target groups. Financial institutions have gained the ability quickly to detect and respond to fraud attempts. The public sector has also reaped the benefits of data analysis – it has, for example, made it possible to optimise public transport, thanks to the information gleaned from ticket readers, or to improve health care thanks to readings taken by various sensors worn by patients.[109]

Datafication lays the groundwork for new business models developed by big technology companies and platforms (for more on this, see Chapter 2). However, at the same time, datafication comes with significant social and economic consequences as it creeps into many aspects of human life, such as social relations, consumer behaviour, production processes, and political engagement. For example, childhood is being subjected to datafication, something the Children's Commissioner for England criticised in a report entitled *Who knows what about me?* (2018). Children's data is not only posted by the kids themselves or by their parents on social media; it is also collected by intelligent toys, virtual assistants (such as Siri or Alexa) and other devices connected to the internet, and it is gathered via wearable devices worn by youngsters. Data, including biometric information, is also collected by public institutions, from schools to public transport and healthcare services.[110] As we will show in a detailed way later, datafication is the necessary condition for personalisation of products and services. At the same time, datafication often makes privacy a delusion. The greatest challenge for the digital economy is how to strike the balance between the companies' – and governments' – hunger for data and the rights of the consumers.

Networks

The digital economy takes networks that were already typical in the earlier days of the internet economy to a more sophisticated level. The rise of the internet, and then of mobile technologies and better connectivity, paved the way for society and the economy to be 'networked'.[111] That created more ties (relationships) between a larger number of actors (nodes of the network). Socially, this has meant the emergence of new relationships resulting from the possibility of freely participating in a variety of groups and circles. For example, in 2017 40% of heterosexual couples in the USA met online; the authors of the research called this phenomenon 'disintermediating your friends'.[112] In economic terms, this expansion of connected networks has changed the relationship between businesses and customers. Both sides now have more knowledge at their disposal. Customers know the ranges of products better, and firms know their customers' preferences in more detail.[113]

In the digital economy, networks are 'thicker' because people and machines are connected all the time. There is no online or offline but **onlife**, as suggested by Luciano Floridi, of the Oxford Internet Institute. And communication is going on not only between humans but also between humans and machines and between machines themselves (by 2023 half of all connections will be machine-to-machine).[114] Constant digitisation (turning analogue data into digital, machine-readable data) saturates networks with more and more data. At the same time, the recommendation engines propelled by AI allow for faster and better-tailored searches and matches between the nodes.

Thicker and datafied networks have additional effects which **platforms** (such as Amazon, Google, or Facebook) use via their business models (for more see Chapter 2). In the traditional economy, the cost of producing a good or service generally decreased as volume rose. In the case of platforms, economies of scale enhanced by network effects occur both on the supply side (the more things are offered, the lower the costs of distribution). Meanwhile, on the demand side, the more end-users, the more valuable the service provided.[115] Platforms are connecting various parts of the market efficiently and quickly because they make use of new possibilities for data collection, processing, and analysis. As a result, platformisation is expanding into yet more sectors of the economy, and the development of networks is accelerating datafication. This in turn enables more and more personalisation in products and services, making the network even more beneficial from the point of view of consumers. Platforms are being recognised as the key feature of a digital economy. The European Parliament goes as far as to define the digital economy as 'a complex structure of several levels/layers connected with each other by an almost endless and always growing number of nodes. Platforms are stacked on each other, allowing for multiple routes to reach end-users and making it difficult to exclude certain players, i.e. competitors.'[116] To sum up, digital platforms with their products, services and whole ecosystems create **digital infrastructures** built upon existing internet networks. Platforms easily expand into traditional sectors of the economy; also their business and operating models are also emulated by companies from these sectors, adding to expanding **platformisation** of the economy.

Digital transformations

Digital transformation is a comprehensive change in the functioning of organisations (companies and public institutions), enabled by **digital technologies**, and resulting in operational and business model build upon datafication and networks.[117] In a wider sense, separate multiple digital transformations add to the comprehensive digital transformation of the economy and society, understood as the paradigm shift in rules governing the economic and social activity.

This process is essentially dispersed and uneven, and its effects are obviously spread over time, and thus often barely discernible. In a research conducted in 2018 by McKinsey, only 16% of respondents (out of a sample of 1,793 representatives from companies from around the world) claimed that a digital transformation in their company had increased efficiency and that the changes would be long-lasting.[118] The perception of the 'success rate' and the impact of digital transformation may be akin to a **productivity paradox**.

In the USA in the 1970s and 1980s, the ICT sector was among the most dynamic and fastest growing sectors of the economy. Yet, to the considerable surprise of economists, research failed to show that ICT had any real influence on productivity; its average yearly growth in this period was a paltry 0.7%.[119] In 1987 a Nobel prize winner in economics Robert Solow quipped that 'You can see the computer age everywhere but in the productivity statistics.' Other researchers hastened to explain that when a company adopts new technology, that may affect the productivity of the individual firm, but not necessarily of the entire sector.[120] Technology can help a company to raise its market share (through better market recognition or marketing), but it does not mean that production within the sector will change. Increasing one company's sales may mean a loss of market share for another.[121]

More importantly, some researchers have suggested that there may be a gap between the swift development of new technologies and the rate at which they have been applied. Besides, the technologies deployed by companies may be ineffective or mismatched – the sheer pace of technological change leaves little time for testing solutions. Organisations require time to comprehend the possible applications of a given technology and only after a certain amount of time has elapsed do they begin to reap the rewards. Phasing in new technologies does not necessarily mean that companies see increased efficiency in the short term, but it may allow a company to respond better, more flexibly and faster to the market situation.[122] Lower costs for information processing and the introduction of advanced production management systems enable enterprises to handle more products and more variants of them. Investments in new technology often require a company to introduce organisational changes and complementary investments in business processes, organising work, communication, etc. These are costly processes and do not always translate into an increase in sales volume.[123] But they do translate into more flexibility, better personalisation of the products, more transparent supply networks, and at the end of the day – into survival on the more and more competitive market.

Changes induced by technological breakthrough are occurring in the smallest businesses. Thanks to the spread of cloud services and the development of intelligent software, digital change has become far more affordable. Twenty years ago, only large companies could employ advanced warehouse management systems or accounting programs. Nowadays, any store can track sales and inventory using intelligent cash registers, which are basically personal computers with a drawer for cash. Small business owners can handle their accounts with the aid of software or online services. Because there is no need for programming skills to set up an online store, local, small manufacturers can now develop their sales through e-commerce, even selling their wares globally. Inexpensive and simple solutions allow them to communicate easily with potential customers, collect data on consumer preferences, and then analyse it using AI-based cloud solutions.[124] Thanks to global digital platforms, small and medium-sized enterprises are gaining opportunities for global expansion. The internet straddles national boundaries and transforms conventional concepts of location and distance. Companies gain access not only to domestic markets but also to global ones at relatively low costs (more on this in Chapter 6). At the same time, those using local markets have obtained free access to global products. This creates new opportunities, but also requires considerable investment not only in technology, but also in organisational changes, and particularly in employees' digital skills.

In the next chapters of the book, we will trace those separate digital transformations in various areas making up the comprehensive digital transformation of economy and society.

Key takeaways

- The digital economy builds upon the internet economy due to the increasing resources of **data** flowing from billions of hyperconnected **digital devices** and the development of **artificial intelligence**.
- The digital economy is characterised by two interrelated mechanisms of datafication and expansion of networks.
- **Datafication** boils down to deriving **value** (economic, social, and political) from **abundant data** generated en masse via digital devices and analysed in an increasingly efficient, faster, and cheaper way by intelligent algorithms. The value may consist in the processes (e.g., planning, production, and management) being made **autonomous** or in products (goods and services) being **personalised**, i.e., tailored to the needs and expectations of the customers.
- The enhanced access to the internet through the digital devices contributes to the growth and thickening of online (and in consequence also offline) **networks** connecting people, companies, public institutions, machines, and systems. Such networks become the source of data in their own right – i.e., they become datafied. The emergence of the new platform business model results in strengthening some of the existing networks as well as creating new ones through the operation of matching and recommendation algorithms. This way online networks become increasingly datafied.
- The intensification and extension of datafication processes into new areas of economic, social and political life is leading to a **digital transformation**. This is paving the way for the emergence of a new model for the functioning of markets, enterprises, households, and the public sector. Production and consumption processes are changing, as are: the nature of work, forms of employment, companies' business models, and the way public institutions function (and, as a result, the way the global economy does too).

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