The Economics of Digital Transformation

The Disruption of Markets, Production, Consumption, and Work

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3 How is production changing?

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Abstract

In this chapter we trace the progress of digital transformation in the production of goods, describing the emergence of Industry 4.0, aka smart or intelligent manufacturing. We start with a concise description of the key digital technologies that are revolutionising production: the **Industrial Internet of Things** (a network of connected data-generating devices), a new generation of mobile, flexible and AI-operated **robots**, and advanced tools for integrating physical and virtual reality such as **digital twins**. Asserting that Industry 4.0 is based on the efficient use of **data** and **intelligent algorithms** throughout the production process, we show how datafication translates into how companies organise and operate themselves, adding to the vertical and horizontal integration of processes. Datafication of the product life-cycle contributes to the emergence of new business models based on **personalisation** and **servitisation**. Turning then to platformisation, we address the budding role of industrial platforms in coordinating relations within supply chains/networks and the rapidly growing imminence of e-commerce platforms in distribution. We conclude by indicating the fundamental similarities between the processes and outcomes of digital transformation in manufacturing and in service sectors, using the example of the digital transformation of banking.

Industry 4.0

The Volkswagen factory in Poznan, Poland, is a smart factory in the making. At the assembly line for vans, digitally skilled humans work alongside cobots (collaborative robots) equipped with screwdrivers. The cobots are able to sense people around them, so there is no need to keep them in safety cages, as is the case with large industrial robots of yore. The production line, on the other hand, is fully automated. The functioning of 30 robots is monitored by one human worker – the information about sudden breakdown is sent to his or her smartwatch. The factory removed large screens presenting the data, because human workers preferred mobile devices. The parts for the vans are transported by automated mobile trolleys, which will stop when a human gets in their way. The production uses 3D printing (additive printing) for building prototypes

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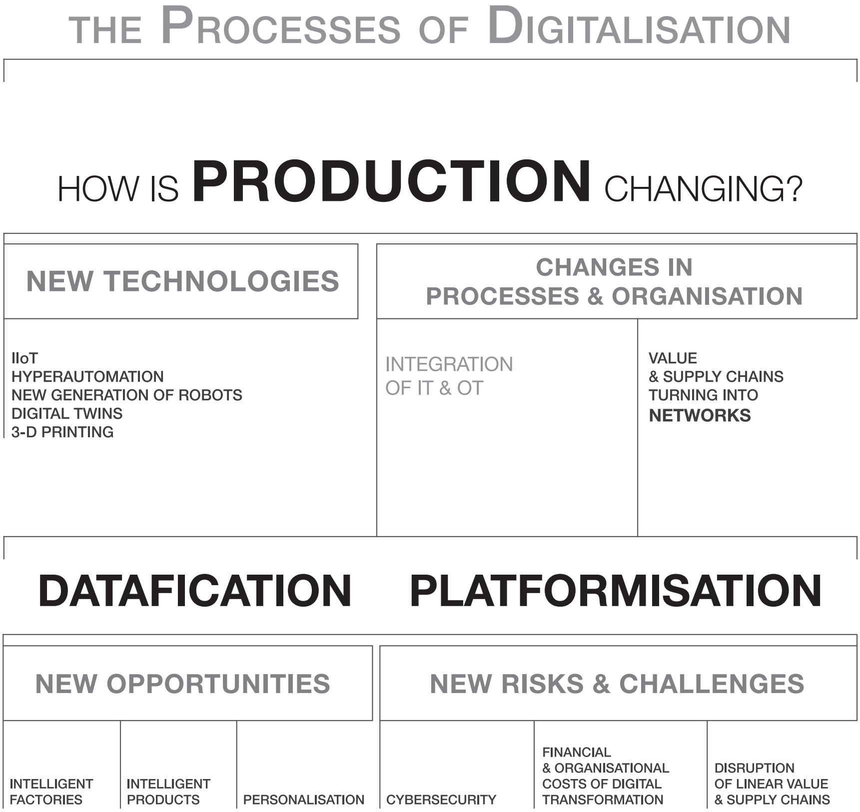

Figure 3.1 How is production changing? (scheme).
Source: Own elaboration.

or production of personalised parts for the vans. While designing new parts, the engineers can use HoloLens – a version of Mixed Reality smartglasses developed by Microsoft – to check their functionality and prepare visualisation for the production team.

But even more sublime changes are on the way. The machine maintenance is still monitored by humans case by case, but the managers are planning to introduce predictive maintenance based on data already collected from all 1200 robots working in the factory. 'We are looking for algorithms that will inform us about the precise wear of the parts of machinery, so we are able to change them just before breakdown, but not too early', says one of the factory managers responsible for introduction of technological innovations. The ultimate goal is to integrate and analyse data from all the sources: from more than 400 IT systems in all the departments, from production to logistics; from robots and 650 systems controlling the groups of the machines and production line; from the remaining

700 devices equipped with sensors, such as screwdrivers, and, finally, numerous separate sensors installed throughout the factory. Integration of data within the company (so called vertical integration) will allow for automated monitoring of processes and their optimisation, making full use of intelligent algorithms.[1]

The decisive stage will include creating a cloud-based, datafied network connecting the factory with suppliers and consumers (based on the horizontal integration of data). This will allow personalisation of production. 'This is especially important today, when people expect that a vehicle in a given configuration ordered today will be ready tomorrow.' In Europe this novel approach to building digital technologies into manufacturing was first came to the attention of industry in Europe in 2011 during the Hanover Messe international trade fair, one of the largest of the world, when members of the business, science, and political worlds presented the concept of Industry 4.0. The idea caught on in Germany, and a vision of German economic policy based on the use of new technologies seduced the federal government as well, leading it to include the concept in an initiative called 'High-Tech Strategy 2020 for Germany'. In 2013 a special working group developed a list of assumptions for Industry 4.0 in order to spur German economic development, developing a bold vision of enterprises operating in connected networks encompassing entire factories, machines, storage systems, and production equipment. The concept rapidly caught on elsewhere in Europe, most speedily in the Nordic countries.[2]

Meanwhile, in the United States, the equivalent concept is 'Smart Manufacturing', and in Asia 'Smart Factories'. Everywhere, however, it is the same phenomenon: **a shift from automated manufacturing toward intelligent manufacturing**.[3] Automated manufacturing emerged in the late 1970s thanks to the move from analogue electronics to microelectronics. Smaller and cheaper computers entered the factories, equipped with a revolutionary software for data acquisition and analysis (such as SCADA) and connected by internal, physically isolated networks (i.e., Ethernet). Communication between information technology systems (IT) and operational technology systems (OT) laid the ground for the automation of most production processes.[4]

Intelligent manufacturing, also known as **hyper-automation**, is contingent on the growing datafication of production: the change in the way data is acquired, processed, and used in order to optimise production, logistics, and sales. This process would have been impossible without an array of innovative technologies, but much of the credit goes to a dramatic fall in the price of sensors (from $22 in 1992 to $1.4 in 2014, and $0.38 in 2020).[5] Their computing power increased radically, partly because of their integration with the cloud.[6] They also became smaller and more energy-efficient, which made it possible to integrate them into existing machinery. Increasingly, multiple sensors, connected through the network of the Internet of Things, started to produce abundant data, which in turn can be quickly and efficiently processed by intelligent algorithms.

Many students of digital transformation are familiar with Marc Andreessen's witticism that 'software is eating the world'.[7] And many of them are convinced that this relates more to the intrinsically digital industries whose main product is data or information, rather than to the physical industries, manufacturing and handling material goods. Take Michael Mandel, an economist at the Progressive Policy Institute, writing in 2018:

> Software has devoured any industry where the final output can be easily reduced to bits. These are the digital industries – including communications, entertainment, finance, and even professional services. The full content of a daily newspaper can be put into a small digital file. But so far software has not been able to eat the physical world. Data is important for physical industries like manufacturing, construction, agriculture, and healthcare, but it is not the main story. The construction of a building requires huge cranes, not just a digital twin of a crane.[8]

Admittedly, digitalisation in physical industries such as manufacturing is much more complicated as it relies upon multiple feedback loops between constant datafication of physical processes, and the translation of data-based decisions into those physical processes. In the case of manufacturing and other 'physical industries', digital transformation results not only from the fact that 'software is eating the world', but more specifically from the fact that 'artificial intelligence is eating software'.[9] Industry 4.0 would have been impossible without the introduction of intelligent algorithms grinding the data with unprecedented speed, often in the cloud.

The adoption of digital technologies is the necessary, yet insufficient, condition for digital transformation. It needs to be supported by wide-ranging changes in the organisation of a company (and particularly in the organisation of work). The comprehensive integration of data from sensors, connected devices, and information and operating systems, underpins the **transformation of the linear value and supply chains into networks**. Every stage of a product's life cycle, from design to maintenance, can be turned into a critical node of a network, which will connect suppliers, contractors, the factory machinery and workers, as well as customers. Manufactured goods are increasingly datafied and complemented by digitally provided services, which enhance their primary functionality. This, in turn, contributes to the growing personalisation of goods and services en masse in response to the individual needs of customers. As a result, manufacturing companies inevitably adopt 'data-first, AI-first' business model.

New technologies in manufacturing

As we emphasised in Chapter 1, intelligent algorithms need to be fed with abundant data. This is why the development of Industry 4.0 is predicated on the **Industrial Internet of Things** (IIoT).[10] That concept can be defined as a dynamic network of connected physical objects equipped with detectors, autonomous sensors, a platform, and applications capable of collecting data and

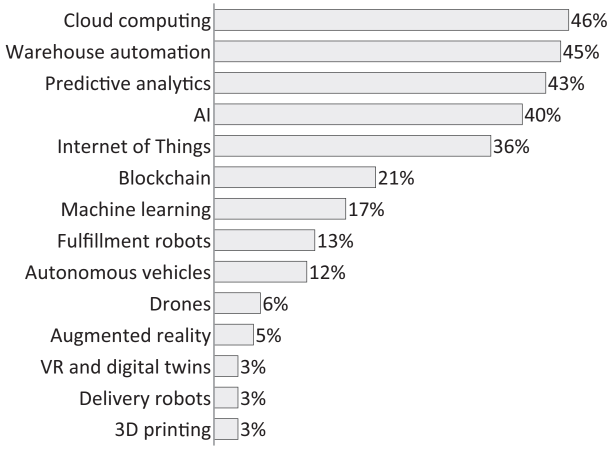

Figure 3.2 Percentage of companies investing in certain technologies (worldwide, 2020). Source: Own work based on Statista. 2020. *What technologies are you currently investing in?*. Chart. In Statista. www.statista.com/statistics/780763/inventory-management-investments-retailers-manufacturers/ (accessed 21 December 2020); n = 601 (industry professionals).

sharing it amongst themselves and with their surroundings.[11] In other words, machines and devices become part of autonomous networks that communicate and interact with each other in a variety of ways. The linear, point-based process of obtaining and processing information, and then applying it to decisions on physical processes (which was characteristic of Industry 3.0) is now being replaced by an uninterrupted, cyclical, and networked process of collecting, analysing, and acting on data, which takes place almost in real-time.[12] Data points are gathered throughout and beyond the production process, including storage systems and supplier networks, and the use of intelligent algorithms allows the data to be ordered, integrated, analysed, and used efficiently.[13]

The sensors that collect the data may be integrated into:

- The **factory,** encompassing the factory floor, storage spaces, buildings, vehicles, and the surrounding grounds), gathering all kinds of data about the movements of physical objects and environmental conditions such as temperature and humidity.
- **Wearable devices** and equipment used by workers. A worker may wear a hard hat equipped with multiple sensors and camera; an intelligent vest collecting data on her movements and vital parameters; or at least a smartband which not only collects data but also vibrates if the deviation from the procedure of movement is detected.[14]
- **Manufactured goods**, which allows for monitoring their use throughout their whole life-cycle. In result, 'Manufacturing goes beyond production

of the physical object, because operating a smart, connected product requires a supporting cloud-based system', said Michael Porter and John Heppleman in an article discussing the role of smart connected products in the functioning of a company.[15]

- **Autonomous vehicles** or **drones**, which are able to work in a collision-free environment thanks to advanced sensors, their ability to communicate with other devices, fast data processing (e.g., thanks to nebular processing) and intelligent algorithms.[16] In the United States, one in ten of large and middle-sized manufacturing companies has already adopted autonomous or semi-autonomous mobile devices, citing cost advantage as their primary motive.[17] Trendsetting, in 2012 Amazon decided to buy a company which developed mobile robots (called Kiva Systems). As of 2020 more than 200,000 mobile robots carried products inside its warehouses.[18]
- Autonomous mobile devices are one type of a wide range of programmable machines capable of autonomous tasks and manipulation of objects that increasingly mushroom in the factories all over the world – **robots**. The spread of robots and the automation of production were typical of the third industrial revolution. 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).[19] In the late 1960s, scientists at Stanford University built an arm that could move in six axes; by the 1980s, however, they were still far from being mobile devices and were unable to sense their surroundings. Currently, the smaller, more efficient and cheaper sensors collect all kinds of data on their surroundings; the data is quickly processed and analysed in the cloud with the help of intelligent algorithms, increasingly with machine and deep learning; and then the decision is put into action by the advanced actuators (components that carry out movements, such as motors, hydraulic systems, signal amplifiers, and hydraulic/pneumatic cylinders).[20]

As a result, robots have become more and more autonomous, able to perceive their environment better, to manipulate objects with greater dexterity and flexibility, and to interact and cooperate ever better with people.[21] A rising number of **collaborative robots (*cobots*)** support workers in industrial production, as well as food production and health care.[22] The advances in computer vision and 3-D depth sensors allow for safer cooperation between human workers and large-scale robots, which up to now worked in safety cages and performed limited movements. In 2020 there were 250 different kinds of cobots available, most of them working in the life sciences and pharmaceutical industries. Nearly half of them were used in packaging or picking and placing.[23] Cobots can be operated by an employee with little experience in programming, easily reconfigured in half a day or redeployed from one department to another.[24] They utilise machine learning algorithms (e.g., image recognition, remembering routes or room layouts), and so teaching them can be extremely quick and simple. For example, Lynx, manufactured by Omron Adept, a robotics company based in California, can memorise the layout of rooms and work out the shortest routes after a single human-guided tour around a building. As a self-navigating transport robot, it has proved its mettle in warehouses, but it is also employed by hospitals, as it can carry loads up to 60 kg. And then there is Panda Powertool, developed by the German company Frank Emik. It is a robotic arm with exceptional precision and flexibility and is able to perform relatively complex manual work. This cobot's unique selling point is its small size (it fits on a tabletop) and its low price, which makes it affordable for small and medium-sized enterprises.[25]

The deployment of cobots is an example of a **Reconfigurable Manufacturing System**, which allows the functionality and efficiency of the production infrastructure to be optimised. These systems consist of modules that, thanks to operational and IT integration, can be easily combined, separated or added to, while an integrated measuring system assesses the condition of the entire system. Mobile and flexible robots, operating on intelligent algorithms, make it easier to reconfigure production lines quickly and cheaply in order to produce small batches and respond to the changing preferences of recipients.[26] This way, the technological processes that are shaping Industry 4.0 will enable advanced personalisation of the final product, resembling of crafts manufacturing, but employing mass production.[27]

The developments in robotics are supported by the deployment of other innovative solutions, e.g., additive (incremental) production using fast design (based, for example, on data obtained from sensors and processed by AI) together

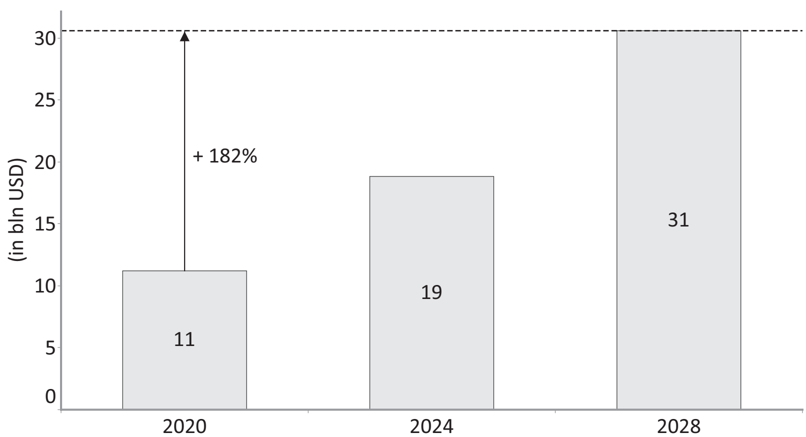

Figure 3.3 Projected global additive manufacturing market size (in billion USD, 2020–2028).

Source: Own work based on PwC, Strategy&. 2019. *Projected global additive manufacturing market size between 2020 and 2028 (in billion U.S. dollars)*. Chart. In Statista. www.statista.com/statistics/284863/additive-manufacturing-projected-global-market-size/ (accessed 21 December 2020).

with 3D printing (see Figure 3.2).[28] The basic raw material for 3D printing is plastic, but other innovative applications include metal object printing using a bidirectional printing technology which involves spreading metal powder and binding it during each machine pass. This results in the creation of durable metal elements at a rate that is as much as 100 times faster than in traditional production.[29]

3D printing is also finding more and more innovative applications in healthcare. By 2026 the market for medical, surgical and pharmaceutical applications will have increased in value from $973 million in 2018 to $3.7 billion.[30] In addition to creating surgical tools, the technology is also useful for building models of organs due to undergo surgery, allowing doctors to prepare better for an intervention in the patient's body. A separate medical application is bioprinting, i.e., applying layer upon layer of a bioink composed of living cells to create an organ. 3D printing also allows personalised implants and prostheses to be constructed.[31] This will allow for true personalisation of healthcare.

The number of robots in production facilities is growing steadily, rising from 1.8 million in 2016 to reach over 2.7 million in 2019.[32] In 2019 70% of them were used in the automotive, electrical/electronic, metal, or machine sectors, although more and more applications in other industries are being found, including in smaller enterprises. Robots are doing handling, welding, assembling, cleaning, dispensing, and processing. Three out of four new industrial robots are being installed in just five countries: the largest share is in China (36% of new installations), followed by Japan, the United States, South Korea and Germany.[33] The design and production of robots is becoming easier and cheaper, too.

Smart facilities, be they factories or offices, are equipped with ubiquitous hyperconnected devices, which makes them a perfect aim for cyberattacks. The number of malicious attacks ramped up in recent years: in 2016 *each* IoT device was attacked 6,000 times a year. In 2017 this number grew to 50,000.[34] Moreover, 40% of security breaches are indirect and come from supply chains or business ecosystems of a company.[35] In response digital companies increasingly invest in cybersecurity solutions based on intelligent algorithms, such as SOARs (Security Orchestration, Automation, and Response) or SIEM (Security Information and Event Management). They collect and analyse data on security threats, automatically respond to low-level security breaches and allow for optimisation of security measure.

Another technology which offers high level of data security is blockchain.[36] **Blockchain** technology is an innovative combination of a number of well-known technologies: cryptographic tools, providing data integrity, and access control; decentralised computing; and software, which acts as a ledger for the blockchain.[37] Each node in the network keeps complete copy of the database, identical to all the other copies thanks to blockchain consensus algorithm. New records are being incrementally added in blocks of data, each such addition invoking a network-wide security- and integrity-assuring procedure. This guarantees that the alteration of historical records is virtually impossible. In a nutshell, it is a constantly updating distributed database. To put it even more

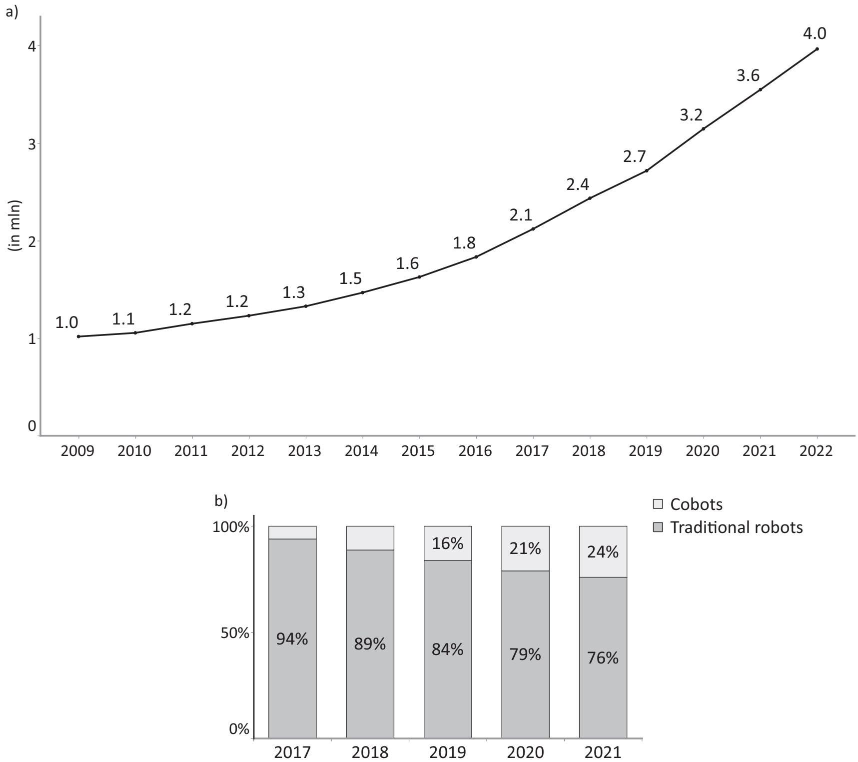

Figure 3.4 (a) Operational stock of industrial robots (in million units, worldwide, 2009–2022); (b) share of traditional and collaborative robot unit sales (in %, worldwide, 2017–2021).

Source: Own work based on IFR. 2019. *Worldwide operational stock of industrial robots from 2009 to 2022 (in 1,000 units)*. Chart. In Statista. www.statista.com/statistics/947017/industrial-robots-global-operational-stock/ (accessed 21 December 2020); IFR. 2020. *Operational stock of multipurpose industrial robots worldwide from 2015 to 2019 (in 1,000 units)*. Chart. In Statista. www.statista.com/statistics/281380/estimated-operational-stock-of-industrial-robots-worldwide/ (accessed 21 December 2020); Statista. 2019. *Share of traditional and collaborative robot unit sales worldwide from 2017 to 2021*. Chart. In Statista. www.statista.com/statistics/1018935/traditional-and-collaborative-robotics-share-worldwide/ (accessed 21 December 2020).

simply, imagine blockchain as a record of transactions kept in a Google spreadsheet shared by many users. Each user can see entries in the registry and can add information to it. However, they cannot change the entries on their own. Initially, blockchains were mainly used to create cryptocurrencies. However, it quickly became clear that the new technology – characterised by its safety, speedy transactions, and the ability to eliminate intermediaries – offered much greater opportunities. Blockchains can either be public and accessible to any

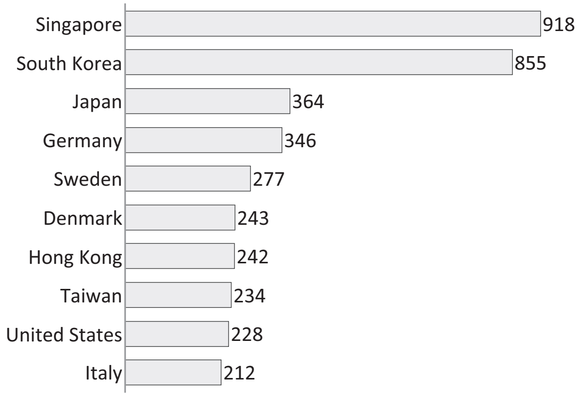

Figure 3.5 Robot density in manufacturing sector (in units per 10,000 employees, selected countries, 2019).

Source: Own work based on: IFR. 2020. *Manufacturing industry-related robot density in selected countries worldwide in 2019 (in units per 10,000 employees)*. Chart. In Statista. www.statista.com/statistics/911938/industrial-robot-density-by-country/ (accessed 21 December 2020).

user (such as Bitcoin, for example) or private and closed, only accessible to a specific group working, e.g., in a specific industry or supply chain. Blockchain solutions ensure high security of data within the organisation. However, their introduction and maintenance is expensive and in the nearest future will be limited to large companies.

Datafication of production

The changing functions of robots illustrate the **growing convergence between information technology systems (IT) and operational technology systems (OT)**, enabling intelligent automation of all production processes.[38] In the past, IT and OT functioned separately: IT was used in management, OT was used to control and monitor machinery and resources.

The Industrial Internet of Things (IIoT) used in factories enables the continuous monitoring of production processes and the adjustment of the maintenance and service plan, thus preventing failures from causing downtime. Integrated with Enterprise Resource Planning (ERP) systems, it manages energy resources and power consumption, as well as optimising production processes more generally.[39] In turn, the integration of the IIoT with Customer Relationship Management (CRM) systems allows companies to tailor automated customer service in real-time, to the profile of a specific customer.[40] Better integration of data enables efficient and seamless integration of the systems, and this, in turn, is reflected in comprehensive organisational and processual transformation.

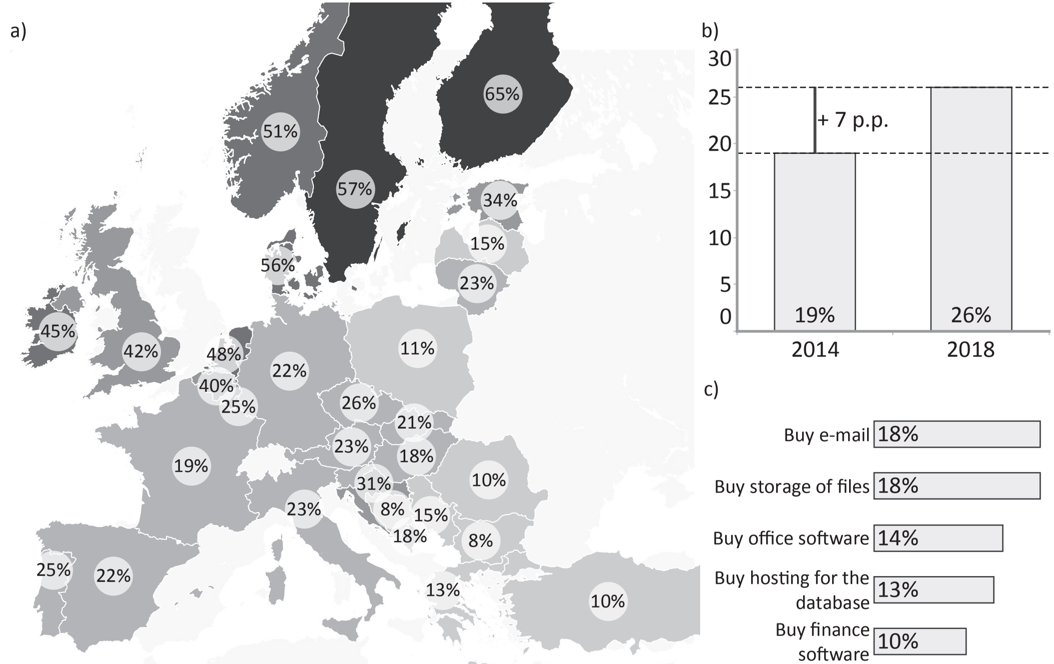

Figure 3.6 Cloud computing services used over the internet (% of enterprises): (a) by country (2018); (b) EU28 (2014–2018); (c) EU8 (by type, 2018).

Source: Own work based on Eurostat data [isoc_cicce_use].

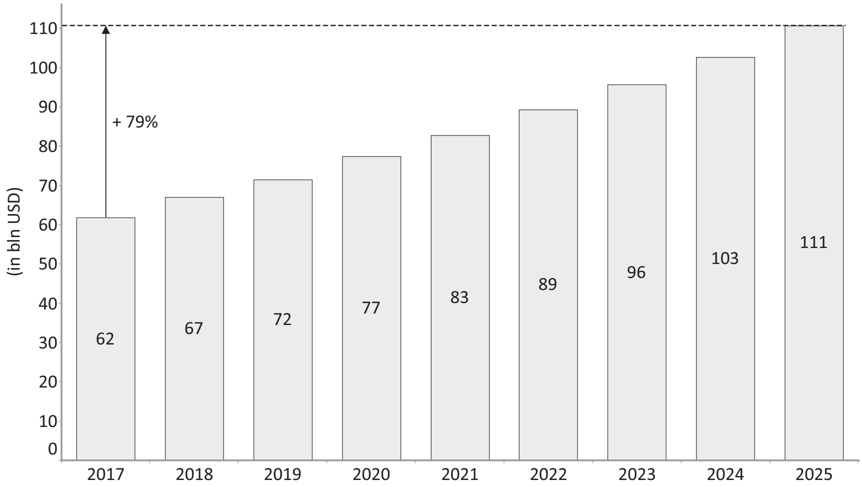

Figure 3.7 Industrial Internet of Things (IIoT) market size (in billion USD, worldwide, 2017–2025).

Source: Own work based on Statista. 2020. *Industrial Internet of Things market size worldwide from 2017 to 2025* (in billion U.S. dollars)*. Chart. In Statista. www.statista.com/statistics/611004/global-industrial-internet-of-things-market-size/ (accessed 21 December 2020).

This convergence of IT and OT is manifested in the development of **cyber-physical systems** (CPS), such as **digital twins**, i.e., digital replicas of physical objects and processes based data that is continuously supplied from a multitude of sensors and processed in the cloud in real-time, using intelligent algorithms.[41] Every physical product or production process can be given its own digital 'model' that allows it, among other things, to be experimented with safely in a virtual world. You can make a digital twin of a machine to test and adjust its design on the basis of the real-world data (this is what Airbus does with its engines);[42] you can build a digital twin of a whole production process to tweak its parameters if need arises (a pharmaceutical company Takeda created a replica of its manufacturing process to experiment and model new chemical and biological reactions);[43] or even of a whole city (as is the case with Singapore, where digital twin allows for flexible response in case of disasters).[44] Digital twin is more useful the greater its precision, which in turn depends on the quality of all the data on the product (or production line) parameters and the speed at which it is transmitted. Unlike Computer Aided Design (CAD) systems, which enable simulations to be carried out in the design phase, 'digital twins' cover the entire product life cycle.[45] They are also much more interactive and even immersive, especially when used with virtual or augmented reality, e.g., experienced via special goggles, helmets, interactive display walls (powerwalls) or Cave Automatic Virtual Environments (immersive virtual reality environment), enabling a whole team of designers and engineers to work simultaneously on a joint project.[46]

Digital twin technology gives an insight into the specifics of how complex machine components operate and allows their functioning to be tested in a variety of conditions. It also makes it possible to optimise the repair and maintenance schedule based on real-time diagnosis of wear and tear affecting machine parts. Simulated factory layouts and systems allow production to be organised better, and then for physical changes to be carried out with the aid of modules and actuators. Digital twins are especially useful for large and complex machines, such as jet engines, whose rotors are subjected to extreme temperatures that reach as high as 1600°C (higher than most metals' melting points). They require constant maintenance, but the schedule is different for each unit, depending on various factors that cause degradation, such as conditions at airports, the number of people on board, the pilot's flying style.[47] That is why aircraft engines constructed by General Electric are equipped with over 100 sensors that continuously collect operational data.[48] In addition, Boeing has found that the use of digital twins has led to a 40% improvement in the quality of aircraft parts and systems. The company's CEO declared in 2018 that CPS technology would be the company's biggest driver of development over the coming decade.[49] Digital twins are also employed by Germany's ThyssenKrupp, which fits out its elevators with intelligent sensors connected to the cloud. Algorithms process the collected data in real-time, flagging potential problems in the functioning of devices and highlighting the need for maintenance. The service is supported by HoloLens – wireless mixed-reality glasses produced by Microsoft, thanks to which specialists can keep track of repair work performed by technical staff.[50] The French rail equipment company Alstom has built a digital twin of a whole rail route between London, Glasgow, and Edinburgh, including every train in the fleet, operating timetables and maintenance regimes.[51] Several companies, with Phillips and Siemens among them, are currently working on the digital twin of a heart, up to millimetres mirroring the heart of an individual patient based on 3D scanning and using real-time data from wearables to prevent health problems.[52] Now, this is a kind of predictive maintenance which may revolutionise healthcare.

Integrating sensors into every part of factory equipment allows for the application of the digital twin model across whole enterprises. The workings of an '**intelligent factory**', along with its supply chain/network, can be recreated virtually based on abundant data points, and management decisions can be made in a highly automated manner, based on data that is continuously connected and processed in the cloud by artificial intelligence.[53] One example of the transformation of traditional production methods into a smart factory is the Hugo Boss factory in Izmir, Turkey. Employing 4,000 workers, the enterprise – in addition to robotisation and automation – is introducing AI systems that analyze data collected from 1,600 tablets located around the factory in order to improve machine- and resource-management processes in real-time. Customers can make changes to the collections they have ordered by using digital twins. Speedy and precise communication and collaboration with customers, taking into account their preferences, has allowed product turn-around times to plummet from six months to six weeks.[54] Another example is a Siemens factory in Amberg, Germany, where industrial computer control systems are manufactured.

> For there is another factory, a virtual version of the physical facility that resides within a computer system. This digital twin is identical in every respect and is used to design the control units, test them, simulate how to make them and program production machines. Once everything is humming along nicely, the digital twin hands over to the physical factory to begin making things for real.[55]

The convergence of IT and OT systems via the IIoT, the automation of processes, together with the growing use of intelligent algorithms, have all led to upheavals in companies. Intelligent factories are seeing unprecedented **vertical integration** of processes, i.e., the combination of technologically separate phases of production, sales and distribution.[56] Hitherto separate levels – of devices and sensors, control equipment, the processing line or the actual production process, and planning and management – are being brought together by an uninterrupted flow of data. Linked-up systems and machines can autonomously respond to changes in production needs and communicate with each other in order to detect defective parts. This ensures greater flexibility and operational efficiency, especially if a company has implemented a modern 'Manufacturing Execution System' (or MES) to manage production.[57] At the same time, the digitalisation of systems and processes from end to end, throughout all the activities aimed at delivering the product to the end-user, is allowing the industry to reach a new level of **horizontal integration**. As a result, a manufacturer's internal processes (demand planning, public procurement, logistics, and after-sales services) are becoming linked to processes that take place where suppliers, business partners, and even consumers themselves are located. The result is a transparent network in which all partners coordinate and optimise not only their processes but also tasks and decisions throughout the entire value chain.[58]

Efficient integration and analysis of data – from both vertical and horizontal operations – is increasingly carried through a cloud-based working environment which reduces the need to develop complex and expensive IT systems on site. These so-called Platform-as-a-Service or Infrastructure-as-a-Service solutions connect devices, systems, applications, and business services, enabling data analysis and access to information in real-time, with minimal involvement of human workers. In simpler terms, they provide for the smooth functioning of the Industrial Internet of Things. A good example of PaaS is MindSphere, developed by Siemens, and available as part of Amazon Web Services, along with an open API. It collects data from sensors, machines, and systems, allows for monitoring of the processes, application of digital twin solution, and advanced analytics with the use of intelligent algorithms. Company resources are connected to the cloud, which allows for monitoring their performance, performing analyses and predictive maintenance, as well as building personalised applications for internal use.[59] Predix, developed by General Electric, performs similar functions by connecting industrial devices to the cloud, and enabling data analysis and access to information in real-time.[60]

Intelligent product

Not only are many aspects of design and production becoming digitalised: so is the lifecycle of products. The spread of 'digital twins' is revolutionising **product life cycle management –** from conceptualisation, to ordering, development, production, distribution, use, service, and even to withdrawal from the market and perhaps recycling.[61] Digital twins shorten the design cycle and allow to respond more quickly to customer needs. In 2015 the engineers at Maserati used them to shorten the time to design a new Ghibli model from 30 to 16 months.[62]

> With the digital copy, the company was able to generate a virtual copy in parallel to the physical development of the car – 100 percent true to the original, down to the last screw. In the development process, the Maserati developers used data from the real and the virtual models simultaneously, utilized that information in parallel for continuous optimization, and were able to reduce both the costs and the time required for development by an astonishing 30 percent.[63]

All this contributes to the creation of a personalised product and facilitates the construction of prototypes, reducing their cost through virtual, fast, and scaled tests. As a consequence, it also optimises decision-making processes, not only in production but also in logistics, sales and related services.[64] In Airbus digital twin is used to coordinate 12,000 suppliers that provide 3 million parts for one of the engines.[65]

An important factor in the creation of new business models has been the increase in the number of intelligent products equipped with sensors to collect data on how they are used throughout their life cycle.[66] Thanks to these, companies can improve their products and services and create a more attractive offering, thereby building a competitive advantage in the market. Technology commentators may have mocked the idea of a smart toothbrush with integrated sensors, which gather data on how scrupulously the user cleans each area in her mouth, but it does give the consumer useful information on mouth hygiene.[67] Acquiring and processing data from each stage of the customer's use of the product, in real-time, opens up – for instance – the possibility of creating a digital representation of the product, one which the client can reconfigure using intuitive design tools (such as Configure One software),[68] or even by using a digital twin.

Intelligent products also allow companies to create a range of complementary products and services related to a product's use, thus expanding opportunities for **servitisation** (we write more about this in Chapter 5).[69] A precursor to servitisation was Rolls Royce, which in 1962 began to offer customers a 'power-per-hour' package: the purchase of an aircraft engine could be supplemented by paying a fixed price to have the engine serviced and parts replaced. In 2002, the company's 'CorporateCare' package even included hardware monitoring, made possible by built-in sensors and faster servicing in authorised centres scattered around the world. As part of the company's current 'TotalCare' service package, it now rents engines and collects data from them on an ongoing basis, allowing the company to plan maintenance. Elsewhere, Caterpillar, a manufacturer of construction machinery, offers a remote tracking and monitoring service in order to provide updates and 'preventive maintenance'.[70] Another example of successful servitisation is changes introduced by IBM: in the 1990s the company began moving away from the production of computers in favour of providing consulting services for enterprises, and then to focus on creating specialised and advanced software.[71]

Servitisation adds to business models that involve subscribing to, or renting, a product without transferring ownership to the user.[72] Ultimately, it boils down to 'building revenue streams for manufacturers from services'.[73]

> Rather than simply selling a piece of industrial hardware, manufacturers can sell customers a contract to provide highly streamlined, AI-powered maintenance and repair services for that specific product. The upside for customers? Less downtime due to machine failure and fewer burdensome repair costs. The upside for manufacturers? They're now able to leverage the data generated by IoT sensors placed within their devices into revenue that's generated over the lifecycle of their product.[74]

To balance this enthusiastic approach, it is worth noting that servitisation in facts entails growing and constant dependence of the customers to the provider of the services built around the product. All physical products can be turned into a kind of connected hardware, useless without the software provided by the producer (we return to this thread in Chapter 5).

Platformisation of production

The digital transformation of a production company not only changes its internal structure but may also result in a radically new business model.[75] The changes here come down to the use of data's potential to break down established value chains and at the same time open up new sources of income. Traditional companies were based on linear value chains, which often transcended national borders. The dominant model was called a pipeline as it offered a straightforward way of value creation and delivery from the supplier of raw materials through the producer to the customer. Traditionally, a company designs a product, a good or service; then it is manufactured or produced, and, finally, it is offered for sale to individual and business customers. The ideal process of production was lean – a concept based on the principles and tools of the Toyota Production System (TPS). The TPS streamlined the use of the resources and the time devoted to developing new products by developing timely delivery systems, standardisation, and improvements in how staff worked.[76]

Currently, the growing abundance of data on each stage of value creation allows for building new connections between suppliers, producers, and customers. A simple pipeline transforms into a complex network of dynamic relations between all the participants in the production process. It is supplemented by a transition from centralised to decentralised production. The former entails carrying out complete production tasks within a single plant or in a multi-facility organisation with a central plant and a network of organisationally related entities. Decentralisation, on the other hand, is the creation of networks of autonomous, intelligent units that exchange information and configure themselves in order to optimise the production process and achieve an efficient result. Lean manufacturing is being replaced by agile manufacturing, based on a flexible, data-driven organisational approach and reconfigurable manufacturing systems. Focusing on smaller batch sizes or even single products, reducing time to market, and maintaining direct contact with the consumer allows companies to respond speedily to changes. It is then possible to meet individual customer needs while controlling costs and quality, and while keeping prices down.

This is the idea behind **production platforms**. Platforms can be built around one or several of the nodes in the value chain; platforms may grow out of a product via servitisation. The integration of processes and data in the not too distant future will allow entities to operate in a distributed system, i.e., in a network. This will affect all actors in the production process, starting with those managing and controlling the production process, to those creating systems and managing suppliers and subcontractors with the aid of those systems, to those supplying materials and semi-finished products, to engaging subcontractors and employees, to customer outreach and maintenance/servicing. In this system, production platforms will end up as a kind of intermediary, an integrator of all the above-mentioned actors. As Michael Mandel writes:

> industrial companies now have the capability to create manufacturing platforms, both open and proprietary. These platforms would be analogous to today's multi-sided internet platforms, like app stores, social media, or advertising networks. Platforms are built upon a ceaseless flow of small packets of data that are rapidly routed to the desired destination. By contrast, these new manufacturing platforms would be mixed cyber-physical systems consisting of functions such as design, production, and distribution running as separate services on top of an advanced distribution network of

goods. By analogy with the digital world, it is useful to think of this new physical network of goods as being 'packet-switched', indicating greater flexibility and lower costs than the previous generation of distribution.[77]

While production platformisation is taking place, the organisation of the value-added chain is also changing. The development of technology in the 20th century allowed it to fragment and paved the way for linear collaboration. On the other hand, digital technologies make it possible to rip the chain apart and distribute work across many levels. The very production process itself may soon be treated as a special service that will be available to companies and even retail customers (Manufacturing-as-a-service). For example, Dassault Systemes' 3DExperience Marketplace connects potential customers digitally with producers. Customers send their projects to producers who quickly deliver a precise quotation, reducing bureaucracy and costs. The platform then passes the order to an available manufacturer that best meets the technical and location requirements.[78] Another platform called Xometry, operating since 2014, provides access to 3D printing technology and metalworking. Xometry supplies clients with a geometric analyser (called 3D Hubs) that allows the order's parameters to be tweaked, and it also comes up with almost instant order quotes based on AI analysis.[79]

Platforms such as Xometry give companies a fast and effective way to use another firm's production capacity to obtain the parts or devices they need. As a result, they can reduce inventory, but above all they gain access to a wide number of potential suppliers. A report released in 2017 on *Digitizing European Industry*, prepared for the European Commission by a working group that deals with industrial platforms, emphasised that the creation of platforms is crucial to the way that smart factories operate. The report argued that the platforms would acquire data from machines – not only to allow them to monitor and control applications but also to provide it to external entities that could use it to create new applications. The next step would be the creation of an ecosystem connecting multi-sided markets, enabling the production of new and innovative products and services. New global standards will also emerge as a consequence. The report's authors argue that platforms present a solution to many challenges facing the manufacturing industry: they enable agile and more flexible approaches to production, based, among other things, on the use of automation and robots, mass personalisation, and servitisation of the product (building the product up with additional services), and finally, they increase energy and resource efficiency.[80] Industrial platforms open up completely new opportunities for companies (including small and medium-sized ones) to reach global markets. By participating in network-related value creation and by leveraging the results of this network, they can strengthen their competencies and compete more effectively with larger players. Their role is no longer restricted to that defined in the linear model of the value creation chain; instead, it may change depending on the project and the partnership that has been created within the network. The development of Industry 4.0 – i.e., the combination of human contextual decision-making skills and the precision and regular input of automated cyber-physical systems driven by intelligent algorithms – may give rise to **rapid growth in productivity and speed up economic development**. However, this will only happen if enterprises manage to change tack and follow a path of intensive digital transformation.

Datafied distribution

One of the key manifestations of the internet revolution has been the emergence of a brand new sales channel: e-commerce. Initially, most distance-based purchasing of goods and services took place over the telephone, via fax and even via television, but the increasing availability of computers for individual users, a decrease in hardware prices, the popularity of the internet, and user-friendly graphic browsers, all created a new paradigm. The internet became fashionable, and the number of users grew rapidly. From the mid-1990s to 2001, everything to do with the net seemed to have a golden future: a huge variety of online stores, auction platforms, and various forms of e-enterprises, often devoid of realistic plans, sprang up like mushrooms after a downpour. The bursting of the dot-com bubble in 2001, however, swept away a large number of new companies. Those that survived – especially Amazon and eBay – have achieved impressive financial results as the growth of the e-commerce market has resumed.[81] For businesses wading through the digital transformation, this sales channel has created unprecedented opportunities. By analysing increasingly large data sets from various online sources, the seller or advertiser can learn more and more about the consumer. Website visits, social media activity, individual clicks, comments, likes: all of these allow companies to create profiles of customers and contact them with personalised offers. The data are useful for dividing up the market and creating a variety of pricing policies, as well as for tailoring personalised, interactive and content-rich advertising copy and content.[82] The data also allow for multi-pronged analysis of the competition.[83]

The further growth of e-commerce will depend on developments in logistics – fast shipping goods from the seller to the customer. Companies that can quickly provide customers with tailor-made products will gain a competitive edge. This is what Jeff Bezos understood better than anybody: 'They want fast delivery; they want vast selection.'[84] The key challenge will be the '**last mile' problem**, i.e., the final, most unpredictable stage of delivering goods to the consumer. Smaller companies make use of external delivery companies, which increasingly develop and adjust the existing infrastructure. For example, in Poland the growing e-commerce sector uses not only face-to-face delivery by the couriers and thickening network of parcel lockers, but also includes the local shops and groceries as last-mile delivery points.

Reflecting the trend characteristic to other areas of the digital economy, distribution will be increasingly dominated by online platforms. E-commerce giants develop their own delivery platforms based on large logistics centres with myriad

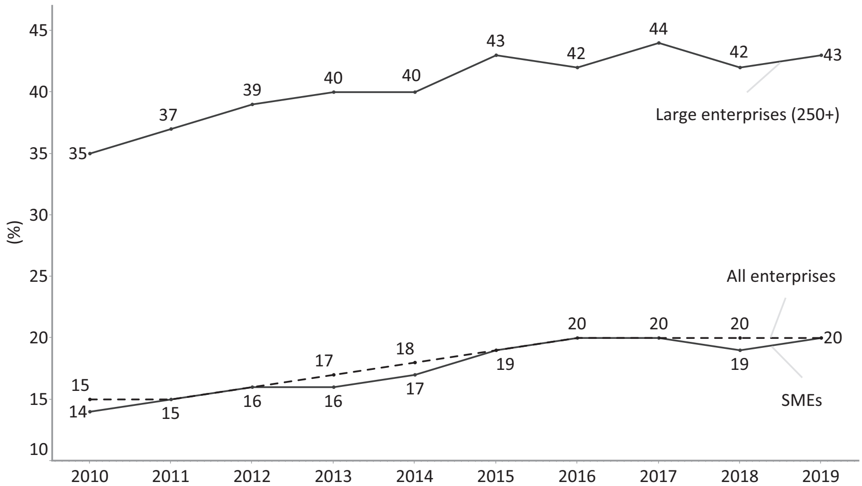

Figure 3.8 Enterprises with e-commerce sales (% of EU28 enterprises, 2010–2019).
Source: Own work based on Eurostat data [isoc_ec_eseln2].

delivery points closer to the consumer: this is the model adopted by Amazon. In 2019 the company operated 500 logistics facilities in the United States and 1100 around the world.[85] In 2012 it paid $775 million for Kiva Systems, a producer of logistics robots, thus kick starting a new branch of development – Amazon Robotics. The corporation then introduced robots to warehouses and service centers around the world, cutting the time needed to prepare an online order for shipment (click-to-ship) to a mere quarter of an hour. It took, on average, four to five times longer for a person to do the same task. Currently, Amazon has an army of over 100,000 robots and plans to add many more.[86] Some of Amazon's warehouses also use an internal automatic transport system, made up of roller conveyors and forklifts equipped with sensors which let them manoeuvre in warehouses with narrow aisles, and which also display information about the load status, the tilting angle of the drive wheel, hours worked and lifting height. The changes that have been introduced have tripled the number of orders handled annually – to over one and a half million currently. Additionally, since 2014 the company has invested $39 billion to build an extensive delivery network. In 2019 Amazon delivered nearly half of its 2.5 billion international packages using its network instead of external delivery companies, and according to the Bank of America Global Research it is 'approaching a truly vertically integrated logistics network on par with the largest delivery companies in the world'.[87] Amazon aims at widening the base of customers in its Prime model, introduced in 2015, promising them the next day delivery.[88]

The Chinese Alibaba also boasts that it can deliver anywhere in China in 24 hours, although it does not define itself as a logistics company. 'We partner

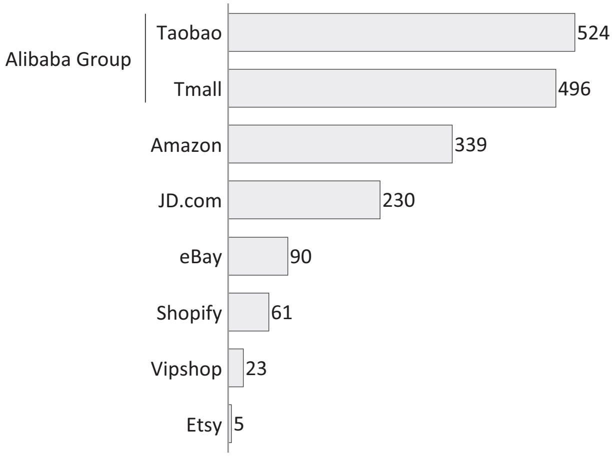

Figure 3.9 E-commerce platforms' gross merchandise volume (GMV) (in billion USD, fiscal year 2019/2020).

Source: Own work based on Alibaba Group. 2020. *Fiscal Year 2020 Annual Report*. https://doc.irasia.com/listco/hk/alibabagroup/annual/2020/ar2020.pdf (accessed 28 January 2021); eBay Inc. 2020. *Form 10-K. Annual Report for the fiscal year ended 31 December 2019*. http://d18rn0p25nwr6d.cloudfront.net/CIK-0001065088/d33d35e7-32e8-4a9c-ad67-12baec291433.pdf (accessed 29 January 2021); Fareeha Ali. 2020. *What are the top online marketplaces?*. Digital Commerce 360. www.digitalcommerce360.com/article/infographic-top-online-marketplaces/ (accessed 29 January 2021); Etsy. 2020. *2019 Integrated Annual Report*. https://s22.q4cdn.com/941741262/files/doc_financials/annual/2019/Etsy-Annual-Report.pdf (accessed 29 January 2021); Vipshop Holdings Limited. 2020. *Form 20-F. Annual report for the fiscal year ended 31 December 2019*. https://ir.vip.com/static-files/1765e7ba-b345-471b-b20e-435957118261 (accessed 29 January 2021); JD.com, Inc. 2020. *Form 20-F. Annual report for the fiscal year ended 31 December 2019*. https://ir.jd.com/static-files/fc93d5dd-9437-4141-9191-f960ba46874b (accessed 29 January 2021); Shopify Inc. 2020. *Form 40-F. Annual report for the fiscal year ended 31 December 2019*. https://s23.q4cdn.com/550512644/files/doc_financials/2019/ar/0efb0f8e-be6a-47d9-b0d6-11a92482dbd3.pdf (accessed 29 January 2021).

with others for this', emphasised Jack Ma in 2017.[89] The logistics arm of Alibaba, called Cainiao Network Technology is an open platform streamlining collaboration between merchants and 3,000 logistics partners and 3 million couriers from 15 top delivery Chinese companies and 100 international ones.[90] In May 2020 Cainiao introduced a three-year initiative to deliver packages within 24 hours in China (for 3 cents) and 72 hours globally (for $5).[91] *Time* correspondent Charlie Cambell, writing in November 2020 from Hangzhou, observed that the company endeavours to create

> a single ecosystem for all logistics firms across the world to plug into, allowing for the seamless transfer of goods between companies and jurisdictions. Just as myriad smartphone makers all operate on Google's

> Android, Cainiao envisages thousands of independent logistics firms can operate within its system, sharing everything from labelling standards to customs information.[92]

Cainiao has already put to use a small automated vehicle called Xiao G to distribute packages nearby its depot in Hangzhou. Both the American and the Chinese e-commerce giant are toying with the idea of drone delivery but it is still in its infancy. In 2017, Flytrex, an Israeli startup, experimented with drones to deliver goods in the suburbs of Reykjavik. To begin with, drones carried goods dispatched by a local e-commerce store across a bay and left them at a designated place where a courier picked them up. In the summer of 2018, Flytrex drones moved on to attacking the 'last mile' and began delivering to suburban customers' doors (naturally, those living in places that were relatively easy to navigate).[93] In 2020 the drones were tested by Walmart to deliver groceries in Fayetteville, North Carolina.[94]

Most importantly, both e-commerce behemoths know how to crunch data efficiently to ensure data-driven predictions of customer demand. Sangeet Choudhary emphasises that 'data is the reason Amazon gets this right'.[95] For example, data insights collected from the deliverers allow for matching the quickest routes of delivery; comprehensive datafication of warehouses allows for predictive ordering of the lacking products.

Platforms are also widely used in long-distance logistics. In 2019 nearly half of the shippers surveyed by Transport Intelligence, a British consultancy, used an online forwarding platform.[96] Digital platforms connect and match shippers (manufacturing and retail companies) and service providers (logistics services, freight forwarders). One of such platforms, Flexport, connects more than 10,000 clients and suppliers around the world, offering them logistics services (ocean, air, truck and rail freight, transport of containers, and warehousing), trade services such as customs brokerage, as well as financing and insurance.[97] An intuitive dashboard allows for introducing data analytics and making adjustments along the value chain. Another such platform, TradeLens, developed by a logistics company called Maersk in cooperation with IBM, uses blockchain to record the stages of the shipping process. Documentation and procedures are completed automatically and without delays.[98]

Admittedly, the use of information and communication technologies in logistics is nothing new: satellites began tracking sea and rail cargo several decades ago, and truck drivers have been using electronic logs for over two decades. Logistics 4.0, however, is characterised by ever more **datafication**: the growing volume of data obtained from an increasing number of connected sensors or devices is being more efficiently processed in the cloud by intelligent algorithms. The result is growing automation and a streamlining of the delivery process: goods can be prepared for shipment with the aid of robots,[99] and thanks to the integration of processes, their shipping becomes faster and more flexible. New technologies of track-and-trace also allow for better quality control in the supply chain: Hyperledger Sawtooth monitors sensors used to tag each fish caught, and catch data is then entered into a blockchain, allowing consumers to find out a detailed history of a dish when they order it in a restaurant.[100] Sensors and blockchains are used similarly by de Boer, one of the largest diamond producers in the world.[101] Firms can manage their relationships with suppliers more efficiently – data analysis improves auditing, affects timeliness, and allows companies quickly to spot problems with the creditworthiness of a business partner. Datafication of the supply chain/network means better resource planning (human, material, and equipment), and this, in turn, improves process optimisation and enables faster reactions to changing market conditions.

The digital company

In this chapter, we focused on the dimensions of digital transformation in manufacturing. But the production is changing in each and every sector of the digitalising economy, be it production of material goods or services. As Jack Ma of Alibaba puts it. 'In the next ten years all industries will change due to AI, big data and cloud. Industries will be turned on their head.'[102] Everywhere adoption of digital technologies results in more efficient use of ever more abundant data, achieved with the help of ever more intelligent algorithms. Companies can optimise their operations, manage their supply chains/networks, and satisfy their customers' needs, producing personalised goods complemented with an array of digital services. Traditional market advantage, built within a given sector, can vanish in the face of digital disruption brought about by the datafied companies, producing material goods. Here, a virtuous circle emerges: the more datafied companies can make ever more efficient use of data and network effects. Linear value and supply chains can be easily transformed into networks overcoming the sectoral divisions – until each stage of production, each part of the company, starts to resemble a Lego block which can be easily joined with other, external blocks to build new and unexpected synergies. The internal structure of the 'data-first, AI-first' companies becomes more flat, slim, and agile.[103]

The developments described above have been happening already in every sector that deals with services. Digitalisation allows for scaling those services that can be delivered to large groups of people without losing their quality and specificity because they are inherently built on data. Take financial services, which are a vanguard of imminent transformation. Financial institutions have always had great access to abundant data on their customers. Yet these data were used inefficiently, because of slow and selective absorption of technologies of datafication and attachment to traditional forms of providing services. Banks focused on the development of digital banking and did not appreciate the fact that the widespread adoption of connected mobile devices opened the way for innovation in the area of contactless payments. People wanted to bank everywhere and at all times, not just in the evenings at their PCs.[104] Soon banks were faced with the growing competition from fintechs – financial startups that knew how to crunch data with ever faster and more efficient analytics based on intelligent algorithms, and how to leverage their impact through platforms accessed via mobile applications.[105]

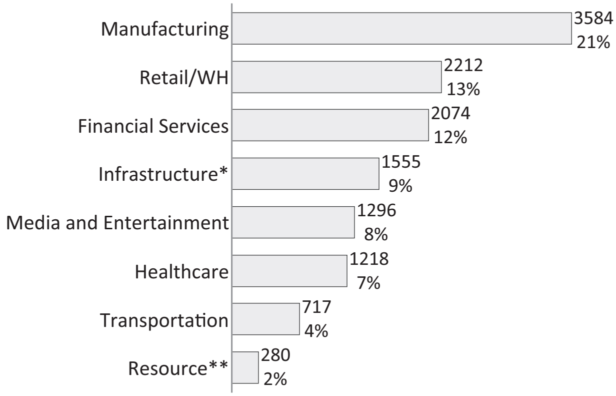

Figure 3.10 Size of the enterprise datasphere (in exabytes, worldwide, 2018).

Note: Sums up to 75%, the remaining 25% covers other industries; * – includes utilities and telecommunication, ** – includes oil and gas (mining), transportation of oil and gas through pipelines or shipping, resource industries, petroleum and coal.

Source: Own work based on Seagate. 2018. *Size of the enterprise datasphere worldwide in 2018, by industry (in exabytes).* Chart. In Statista. www.statista.com/statistics/948851/worldwide-enterprise-datasphere-total-size-by-industry/ (accessed 19 January 2021).

Digital disruption in the financial sector was somewhat slowed down by the weight of legal regulations guarding many of the traditional functions. Traditional financial institutions gained time to learn their lesson and to seriously engage in digital transformation. But Brett King, the author of *Bank 4.0,* believes that the disruption will continue until banking becomes a ubiquitous experience delivered seamlessly in real-time: 'the bank account of tomorrow is primarily an activated, cloud-based value store that reacts through technology where you are using your money. It's not an app, a website or a branch.'[106] Traditional banks, built around departments providing different types of products, usually offered through physical branches, will not survive, because they will be not able to offer personalisation in the shape of frictionless payments, value storage, and access to credit, backed up by intelligent recommendations. Accordingly, the banks will have to change their internal organisation, transforming into platforms built around a 'data-first, AI-first' rule. 'AI will likely eliminate whole swathes of the org chart as it stands today, but AI and data mining and modelling will power elements of almost every interaction', says Brett King. Such platformised banks, with a digitally standardised structure, will be able to negotiate flexible partnerships with fintechs, technological companies offering a range of complementing services, and, more importantly, with techfins, large technological companies supplying a digital layer to every kind of human experience. One such area of collaboration is online and mobile payments, with Chinese companies such as Alibaba and Tencent showing the way. Alipay developed by Alibaba can boast of 1 billion users (as of 2020), and advertises to 'remove barriers between different aspects of life' so their customers 'can enjoy a streamlined way of living, empowered by technology'.[107] The Alipay app enables frictionless online as well as in-store payment (through QR codes) as well as management of bank account and credit card bills.

Digital technologies have also changed the mode of delivery for non-scalable services, which may be offered to a limited number of people at a given time. Many of such services are based on personal, physical, and geographically localised contact between the provider and the receiver, for example, a hairdresser and the client, or a taxi driver and a passenger. They are intrinsically not amenable to digitalisation, but some stages of their provision can be datafied. This goldmine was first discovered by platforms such as Uber and Airbnb, which offered a simple solution to the problem of matching supply and demand for some kinds of services, and provided it via applications embedded in a mobile device. Now platformisation is beginning to expand into more traditional service sectors, such as education. Particularly at the university, datafication will devour all the passive modes of knowledge dissemination, such as lectures, which will be easily scalable through digital channels. The teaching of practical skills and competencies will still, predominantly, require personal interaction, but the process of searching for competent and efficient teachers will be increasingly mediated via platforms such as Coursera or Udemy and their recommendation algorithms.

To sum up, the production of material goods and services will be increasingly datafied, and distributed via digital or digitally enhanced channels of

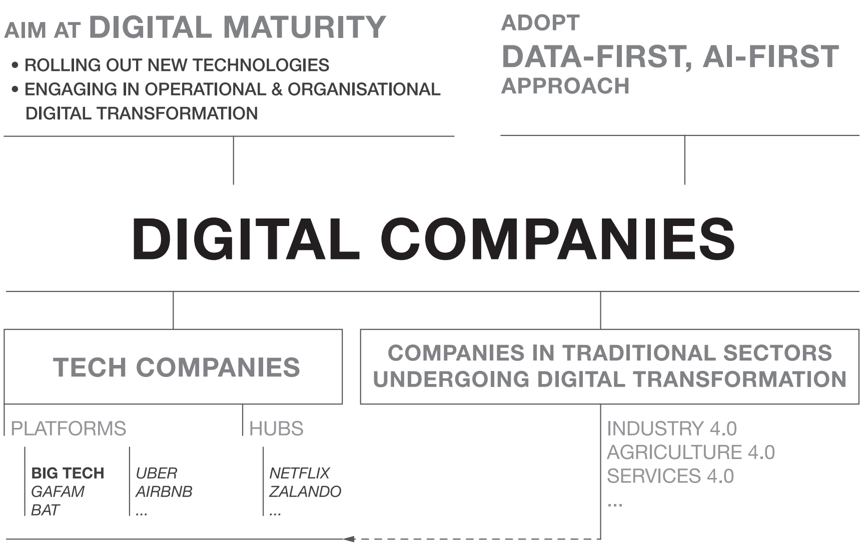

Figure 3.11 What is a digital company?
Source: Own elaboration.

distribution. If the service is scalable, companies will aim at creating their own digital platforms. If it is not, then companies will increasingly use external B2B or B2C platforms to reach potential customers. Value chains will become more fragmented, as small technological companies take over some of their segments. In other words, as Pascal Bornet, the author of *Intelligent Automation* (2020) puts it, 'All businesses are going digital: the winners will be those who do so the quickest and to the greatest extent.'[108]

In the next chapter, we will take a look at the prerequisite of the successful digital transformation – digitally skilled workers. The key factor for enterprises is finding or training up appropriately qualified **employees** who can work alongside intelligent robots and systems that incorporate AI.

Key takeaways

- The rules of **digital transformation** apply to all sectors of the economy, from the manufacturing of goods to the production of services.
- In manufacturing digital transformation boils down to efficient collection, analysis and use of **abundant data** to optimise design, production, sales, and distribution. Data is flowing from all entities engaged in design, production, sales and distribution: i.e., digital devices and machines, vast array of robots and cobots equipped with sensors, suppliers, and contractors along the supply chain/network, and intelligent products. This is the value provided by the key technologies that feature in **Industry 4.0** (such as **intelligent algorithms**, the Industrial Internet of Things, a new generation of robots, and digital twins).
- The push to datafy all phases of production and distribution is resulting in organisational changes: the incessant flow of data and its analysis by intelligent algorithms supports **vertical** (within the company) and **horizontal integration** (within the product life-cycle, i.e., supply chain/network). All companies aiming to achieve competitive advantage will have to adopt a business model based on the rule of '**data-first, AI-first'.**
- Digital transformation is propelled by the drive to **personalise** offerings in response to the growing expectations of customers, who want tailored and yet readily available goods and services. Personalisation will require the **flexible reconfiguration of manufacturing systems**, based on advanced simulation of a product via digital twins, fed with specific data on customer's needs and expectations. Personalisation is also increasingly provided through **servitisation**, where a physical good is complemented by a range of services that boost its basic usefulness.
- **Datafication** in all sectors of the economy, including manufacturing and services, supports **platformisation**, particularly in sales, distribution and logistics. Platforms use abundant data and intelligent algorithms to efficiently match producers with suppliers, contractors, deliverers, and customers. Large companies will tend to build their own platform ecosystems, while smaller firms will use the infrastructure provided by tech companies.

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