

Digital age

Automation, digitalisation and platforms: Implications for work and employment



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Glossary

3D printers: machines that can create physical objects from three-dimensional digital models, generally by laying down successive layers of material.

Algorithm: a set of precisely defined steps and rules to accomplish a task.

Automation of work: the replacement of (human) labour input by machine input for some types of tasks within production and distribution processes.

Coordination by platforms: the use of digital networks to coordinate economic transactions in an algorithmic way.

Digital age: an historical period marked by the widespread use of digital technologies in different aspects of human activity.

Digital goods: strings of bits (digital information) that have economic value.

Digital revolution: a general acceleration in the pace of technological change in the economy, driven by a massive expansion of our capacity to store, process and communicate information using electronic devices.

Digitalisation of processes: the use of sensors and rendering devices to translate (parts of) the physical production process into digital information (and vice versa).

Division of labour: the separation and allocation of tasks to different persons cooperating in an economic process.

Economic institutions: rules, structures and mechanisms of social coordination of the economic process.

Employment conditions: contractual and statutory conditions of the work relation that have an impact on the well-being of the worker.

Industrial relations: the relatively institutionalised ways in which workers and employers organise their relations and settle their disputes.

Intellectual property rights: monopoly rights given to the creators of informational goods over their use and reproduction, for a given number of years, backed and imposed by the state.

Long-tail markets: massively large markets with near-perfect information, where there is economic value in the provision of even extremely rare goods or services.

Massive Open Online Courses (MOOCs): free or very low-cost courses available on the internet that use online videos and texts, together with interactive exercises and algorithmic monitoring of progress, to provide an alternative to face-to-face education.

Network effects (also demand-side economies of scale): a situation in which the value for consumers of a particular type of good increases with the number of users.

Occupations: coherent bundles of tasks that require specific skills, corresponding to different positions within the division of labour in society.

Tasks: units of work activity that produce output and which are coherently bundled into occupations.

Technology: in a general sense, the tools and methods used for carrying out the economic transformation process.

Internet of Things (IoT): sensors attached to outputs, inputs, components, materials or tools used in production.

Winner-take-all markets: markets in which a single provider of a particular type of good or service tends to concentrate the vast majority of economic activity.

Working conditions: the physical and psychological requirements and attributes of work and its environment that have an impact on the well-being of workers.

Zero marginal costs (as applied to digital goods): no marginal costs for non-rival and infinitely expandable digital goods.

Introduction

From the digital revolution to the digital age

The digital revolution can be defined as a general acceleration in the pace of technological change in the economy, driven by a massive expansion of our capacity to store, process and communicate information using electronic devices. Although some of its key underlying technologies and scientific foundations were developed between the 1950s and 1970s, the ‘big bang’ of innovations and applications of digital technologies was triggered by the invention of the microprocessor in the early 1970s – a general-purpose programmable electronic device capable of processing digital information. The continuous increase in performance and decrease in the cost of microprocessors over the next four decades facilitated a very rapid spread of different digital technologies, such as the personal computer, the internet and mobile phones.

The digital age can be defined as a historical period marked by the widespread use of digital technologies in different aspects of human activity, including the economy, politics and most forms of human interaction. This widespread use of digital technologies implies a profound transformation of social, economic and political systems, in the same way as the steam engine or electricity transformed past societies. This paper will set out a conceptual and analytical framework to assess the implications of the digital age on work and employment.

In order to understand why it is important now to study the implications of the digital age, this introduction will provide some historical context and a broad interpretation of the significance of the digital revolution, synthesised in three main contentions that underlie the approach of the rest of this paper. These arguments derive from the work of economists Chris Freeman and Francisco Louçã (Freeman and Louçã, 2001), and Carlota Pérez (Pérez, 2003).

The first contention is that changes in the methods and tools used in the economy tend to cluster around periodic ‘revolutions’, rather than following linear and incremental trends. The reasons are both technological

and socioeconomic. From a technological perspective, since each new technology is essentially a recombination of previous ones, the introduction of a new general-purpose key technology, such as the microchip, opens up a myriad of new possibilities of recombination and applications. This generates a self-reinforcing process of fast technological change, with each ‘new’ technology opening up further possibilities until they are eventually exhausted.

From a socioeconomic perspective, since production technologies are embedded in social structures, the introduction of new technologies will initially struggle against the existing organisational forms, cultural attitudes, vested interests and institutional settings (consistent with the pre-existing production technologies). However, when such resistance is overcome, the same organisational forms, interests and institutions can foster the diffusion and further development of these new technologies. These technological and socioeconomic factors give technological change a ‘syncopated rhythm’ similar to other and in some ways related to evolutionary processes, such as Kuhn’s *The structure of scientific revolutions* (Kuhn, 1962) or the punctuated equilibrium of biological evolution.

Thus, the digital revolution represents the most recent of a long sequence of periodic bursts of innovation and change in the tools and methods used in the economy. This is all due, as already mentioned, to the invention of the microprocessor and microchip – a general-purpose technology that has seen a steady reduction in production costs and an equally steady increase in capabilities. It has created a whole new set of products and industries with massive investment opportunities, but it has also created socioeconomic imbalances. Indeed, the microchip has facilitated new forms of economic organisation that have slowly spread to more and more sectors and activities – a process that is ongoing.

As with previous technological revolutions, the digital revolution requires a paradigm change in the organisation of the economy, which in turn will bring about new social structures and the need for new institutions.

Box 1: The historical significance of the digital revolution

This paper roughly follows the approach of Chris Freeman, Francisco Louçã and Carlota Pérez, who interpret the digital revolution as the fifth technological revolution of capitalism over the last 200 years (Freeman and Louçã, 2001; Pérez, 2003). The four previous technological revolutions were: the initial Industrial Revolution (circa 1771); the steam and railways revolution (circa 1829); the steel, electricity and heavy engineering revolution (circa 1875); and the oil, automobile and mass production revolution (circa 1908). Each of those revolutions triggered a paradigm shift of the economy, and the cycle of installation-crisis-deployment-stagnation (Pérez, 2003), discussed in this chapter.

However, in the literature there are also very different arguments about the historical significance of the digital revolution. The most extreme and opposing view has been propounded by the American economic historian Robert J. Gordon (2016), who interprets digital technologies as a

peripheral set of innovations mostly relevant for leisure industries, but with very little effects on growth in the long run (in fact, the digital age would coincide with a period of secular stagnation, since the fruits of the Industrial Revolution have been already reaped).

Others speak about a third Industrial Revolution (Rifkin, 2011) or even a fourth (Schwab, 2017); such arguments are closer to the Freeman-Pérez framework, although more loosely constructed. The very influential Massachusetts Institute of Technology (MIT) researchers Erik Brynjolfsson and Andrew McAfee interpret it as ‘the second machine age’, giving it a much larger historical significance, equivalent to that of the original Industrial Revolution (Brynjolfsson and McAfee, 2014). Furthermore, some scholars believe the digital revolution to be the trigger of an evolutionary leap in humankind equivalent to that of the emergence of Homo sapiens (Kurzweil, 2005; Harari, 2016).

The second contention is that there is a time lag between the initial big bang of innovation provoked by a technological revolution and its full transformation of the socioeconomic structure. As previously mentioned, productive technologies are embedded in socioeconomic structures, and their change, on a large scale, requires a transformation of infrastructures, organisational practices and institutional frameworks, overcoming the explicit (or implicit) resistance of the existing dominant actors and industries.

A typical sequence, from technological revolution to socioeconomic transformation, starts with the appearance of new products and industries, initially at the margins of the economy, but then growing very fast. This rapid growth would attract investment, providing leverage for further innovation and growth, as well as the necessary funding for the installation of new infrastructures and the development of further applications.

This is the initial period (the ‘installation’) of a technological revolution, which in the model of Freeman and Pérez generally lasts about three decades. It is a period marked by growing imbalances between the old and new industries, and the firms and workers that benefit from the new technologies. It is also often associated with a speculative frenzy that ends in a financial crisis (Pérez, 2003). In this installation period, the transformational power of the new technologies remains mostly limited to the associated industries and those most directly related, such as the building of associated infrastructures. The financial crisis serves as

a turning point and a cleansing mechanism for the possible excesses of the installation period, consolidating the structures of the new industries and reducing any excessive levels of expectations.

After this crisis, the new technologies are mature, the new infrastructures have been installed, and the skills and knowhow required for the new tools and methods are widely diffused. Then, the new technologies can spread to other industries and activities where their full potentials can be realised and put into practice. This second period of the technological revolution, which generally takes another three decades after the turning point of the crisis, is what Pérez calls the ‘deployment period’. Over this period, the possibilities afforded by the technological revolution are slowly depleted; this leads to a period of stagnation that prepares the groundwork for the next technological revolution, which then starts the process all over again. This long cycle theory of technological revolution, the most well-known of which was the Fordism of automobiles, oil and mass production (starting around 1908 and finishing in the early 1970s), fits surprisingly well with the development of the digital revolution.

The invention of the microprocessor in the early 1970s facilitated the creation of many new products and customer markets in the margins of the economy, such as videogames and microcomputers. These markets experienced very fast growth rates and developed tools and methods that were subsequently applied to other new and fast-growing products and markets, especially in the development of the internet and mobile phones.

The huge profits of these new industries attracted ever-increasing levels of investment with very high expectations, which ultimately led to the burst of the dotcom bubble in 2001 (perhaps extending to the financial crash of 2008). According to this cyclical model, the deployment period of the digital revolution should be starting now, when the new tools and methods have diffused throughout the entire socioeconomic structure, and the real economic transformation takes place.

This leads to the third contention: for a technological revolution to produce valued and shared benefits to society, the institutional framework has to significantly change in order to deal with the broad socioeconomic implications of the new forms of economic activity. Again, this is a corollary of the social embeddedness of productive technologies. The institutional framework of market economies has to deal with the externalities and contradictions created by economic activity, for instance, providing employment insurance or income redistribution, but it also performs some important regulatory functions, such as employment regulations, competition policies, demand stimulation, education and R&D policies. It is clear that a technological revolution that implies a transformation in the tools and methods used in the economy will also require a significant change in the institutional framework that regulates and helps to coordinate such an economy.

Indeed, the history of previous technological revolutions shows that they have been associated with profound changes in economic regulation and state intervention in response to increasing socioeconomic imbalances and contradictions in the installation phase – following the sequence previously presented.

For instance, the Keynesian welfare state and employment regulation model can be interpreted as an institutional response to the imbalances and contradictions created by the Fordist mass production system (Boyer, 1990). By regulating industrial conflict and employment relations, redistributing income and stimulating demand, the Keynesian welfare model facilitated the full deployment of the Fordist mass production system and ensured that its benefits were more widely shared by the population.

The Keynesian welfare model is an example of a successful reorganisation of the institutional framework to deal with the imbalances and contradictions created by a technological revolution, in this case the Fordist mass production system. However, it is important to emphasise that a successful reorganisation of the institutional framework cannot automatically be assumed. Institutional reorganisations are the result of political processes which have their own logic, which is beyond the scope of this paper.

Technological revolutions tend to generate socioeconomic imbalances and contradictions which the existing institutional framework (developed in and for a different context) cannot resolve. This is likely to lead to some form of political crisis with an indeterminate outcome. It can, for example, be a successful reorganisation of the institutional framework, or perhaps an unsuccessful one, or even no major change at all. This historical argument can also be applied to the subject of this paper. The digital revolution has created significant imbalances and contradictions over the last few decades that are (at least partly) the result of an increasing incongruence between the underlying economic structure and the institutional framework; this is highlighted by increases in income inequality, as well as economic and political instability.

As digital technologies and the associated organisational changes – automation, digitalisation and platforms (discussed later) – extend to more and more sectors of the economy, the contradictions are likely to become even greater. That is why now, at this historical conjecture, it is particularly important to improve our understanding of how the digital revolution changes the nature of economic activity, work and employment. This knowledge should assist the democratic political process in redesigning and reorganising the institutional framework of the economy, ensuring that the digital age is one of prosperity and progress for all – the ultimate aim of Eurofound's programme of work on the digital age and its implications for work and employment.

The rest of this report is divided in four chapters. Chapter 1 discusses how technology, the division of labour and institutions interact with each other as they transform socioeconomic structures.

Chapter 2 presents some of the key attributes of the digital economy, inferred from the observation of the industries and sectors that are at the forefront of the digital revolution.

Chapter 3 introduces three key vectors of change – automation, digitalisation and platforms. In the author's view, these are of greatest significance for understanding the implications of the digital age for work and employment.

Finally, Chapter 4 presents some final remarks and considerations to help guide a research programme based on this conceptual and analytical framework.

1 The foundations: Technological and socioeconomic change

From a material perspective, the economy can be defined as the process of combining and transforming inputs into outputs in order to produce goods and services for human needs. Thus, technology can be defined as the tools and methods used for carrying out these processes. Analysed in greater detail, a technology can be understood as a domesticated natural phenomenon: a device that allows the reproduction and control of a mechanism observed in nature. Most significantly, once a technology has been perfected, it becomes a building block that can be combined with others to form more advanced technologies. Furthermore, technologies can facilitate the discovery and domestication of new natural phenomena (the way microscopes opened up the cellular and microbial levels, and with that a myriad of new possibilities for the life sciences and associated technologies). The possibilities inherent in technology – of recombinations and of uncovering further natural phenomena – lead some authors to describe technological change as an ‘autopoietic’ self-maintaining process, which builds on itself (Arthur, 2009). The more technologies that become available, the more the possibilities for the recombination and discovery of new phenomena and, therefore, the possibility for further technological development. The result is a self-reinforcing process of technological progress – ultimately, the accumulation of (applied) knowledge.

It is important to note that even from this purely technological perspective, technological change is not seen as a continuous process, but one that is punctuated by periodic bursts of innovation. Technologies tend to cluster in domains, groups of technologies that share a family of effects, a common purpose or underlying theory. These become toolboxes for the assembly of new technologies or applications. Bursts of innovation often happen when a new domain is opened up by the discovery or domestication of a new type of natural phenomenon, making a new toolbox of technologies available for further recombination and applications. Also, innovation often results from ‘reclaiming’ (Arthur, 2009), where the application of an existing solution to a different problem allows the translation of the entire toolbox associated with the existing domain into a new one. This is purely a ‘technological’ account of technological change, one that helps in understanding its peculiar self-reinforcing, punctuated and accelerating nature. However, for the purposes of this report, it is problematic because there is obviously something missing. The economy may be

seen as a transformational process, but it still needs agents to enact such a transformation – human beings, whose input into the production process must be coordinated. In this respect, it is useful to distinguish between the two types of mechanisms for the coordination of human input in production processes – technical (the division of labour) and social (the socioeconomic institutions).

Division of labour

‘Division of labour’ refers to the separation and allocation of tasks to different persons cooperating in an economic process. It is an attribute of economic activity that is as important and universal as technology itself. It acts as a mechanism for coordinating the input of different individuals towards a common (productive) goal, which can enormously increase the efficiency of any type of cooperative production. This increase in efficiency is the result of specialisation (which increases the dexterity of workers) and a better coordination of the labour input (which reduces time between tasks, facilitates standardisation, as well as other efficiency procedures).

Division of labour can be understood as a very general purpose organisational method (and therefore – in some ways – a technology). However, it is so universal and important on its own that it is better to consider it separately. A more difficult question to answer is whether the division of labour is a technical attribute of the economy or a social one. On one hand, it is obviously a social attribute, because it is a form of social coordination, as already argued. On the other hand, division of labour can be considered to be a technical attribute of economic activity, since it is a way of increasing the efficiency of a productive process independently of the interests and values of the people involved.

In this last sense, division of labour can be neatly differentiated from economic institutions, which (as will be discussed later) aim to coordinate workers as social beings rather than as inputs into a productive process. Thus, the division of labour is a technical attribute of economic activity: it is a method that allows for better coordination and efficiency of labour input into the economic process. And it is also a social attribute, since the division of labour is a form of social coordination that gives rise to a social structure. The relationship between the division of labour and technology is fundamental to how economic development works in both directions.

Technological change shapes the evolution of the division of labour, by directly changing the production process and the types of labour input necessary. The introduction of new technology into a production process that is organised in a particular way will always require some kind of reorganisation of work: some tasks may change or become unnecessary, while others may be created anew. Consequently, the skills, positions and conditions of workers within the process will also change.

But the division of labour is also a key enabler of technological change. First, the breakdown of production processes into separate tasks facilitates a better identification of problems and potential technological solutions. Second, the specialisation of workers increases their knowledge of the economic process and therefore their capacity to develop new tools and methods. In general terms, the division of labour expands human knowledge of the production process and therefore facilitates innovation and technological change. A good example of how the division of labour and technological change feed into each other is automation – the replacing of human input by machine input for certain production tasks.

Historically, a specific division of labour (and specialisation) has been a precondition of automation, but only if the processes are broken down into very simple, specific tasks that can be automated. The automation of certain tasks has been, in the long run, a key determinant of the opening up of the division of labour: for instance, the importance of routine manual tasks as forms of human labour has decreased dramatically in modern economies.

Technology and the division of labour form the material foundation of the economy as a transformative process. However, the coordination of human input into production is not only a technical problem, but also a social one. Humans have different needs, interests and values, and their input in production requires rules, structure and mechanisms of social coordination – namely, institutions.

Role of institutions

Institutions support the functioning of economic processes by providing stability and social coordination, and by dealing with their external effects. Institutions make the economic process socially sustainable, allowing the material process of economic transformation to proceed while respecting the fabric of society. Given that institutions are necessary for the economy to function, why not recognise them as a category of technical solution to the issue of social coordination? For instance, the coordination of economic activity by the mechanisms of markets and firms anchored in institutions such as property rights, contract regulations and enforcement could be seen as an organisational technology that facilitates a more efficient coordination of economic activity. There is an inherent logic to this: any set of defined rules and principles of behaviour is a method, an algorithm and, therefore, a technology (in this case, one of social coordination). However, it is important to differentiate between organisational methods that explicitly aim at the social coordination of human interaction (institutions) and organisational methods that ostensibly aim at the technical coordination of human input into a productive process (the division of labour or work organisation). The latter may also have social implications (giving rise to power structures, for instance); however, this effect is unintended (in the same way that a technology can have social implications). The whole point of an institution, in contrast, is its social implications.

This may seem like an unnecessary distinction, but it can be important for discussions on economic policy: technology and the division of labour form the technological substrata of the socioeconomic system, which can be associated with very different institutional frameworks. This explains the wide institutional variations that can exist between economies whose overall use of technology and division of labour (their economic development) is very similar. Perhaps the best example is that for a long time a similar underlying economic process (similar technologies and division of labour) existed in two radically different institutional forms – capitalism and state socialism. It is the institutional framework that determines most directly the distribution of life chances across the population, even if this distribution is constrained by productive possibilities set by the underlying economic structure. In summary, the benefits of technological change and economic development can be differently distributed, depending on the institutional framework that each society sets for itself.

Box 2: Implications of technological change on work and employment

On the basis of the arguments discussed in this chapter, four different aspects of the implications of technological change for work and employment can be differentiated.

- **Tasks and occupations:** the distribution of tasks in the economy and the occupational structure that are directly and continuously changing as a result of technological advances (every new technology involves some new way of carrying out a particular process, and therefore a change in the associated tasks).
- **Conditions of work:** the physical, psychological and environmental requirements and conditions of work (also directly affected by the technology used).
- **Conditions of employment:** the contractual and social conditions of the work, including issues such as stability, opportunities for development and pay (these mostly depend on the institutional framework and labour regulation, with the effect of technology being more indirect).
- **Industrial relations:** the relatively institutionalised ways in which workers and employers organise their relations and settle their disputes; the effect of technological change on this domain is also indirect (affecting the three previous aspects in the areas of interests, power and organisational capacity of workers and employers).

Tasks and occupations and conditions of work are two aspects of the division of labour and part of the material attributes of the economy where the effect of technological change is direct and immediate (it can change directly the types of tasks needed in production and the conditions in which work takes place). In contrast, conditions of employment and industrial relations are part of the social and institutional attributes of the economy; the effect of technological change on them is indirect and more indeterminate.

As with the division of labour, the relationship between technology and economic institutions is fundamental and works both ways. Technological change and developments in the division of labour are continuously changing the nature and structure of economic activity. This changes the needs, interests and values of economic agents and erodes the stabilising and coordinating role of economic institutions. Sooner or later, economic institutions have to reorganise and adapt to new technologies used in production. This also applies to the need to reorganise the institutional framework of the economy in the digital age.

For example, the Internet of Things (IoT) promises a big leap in the efficiency of industrial processes, but it can also transform a factory into an invasive surveillance system.¹ The existing regulations in industrial labour cannot deal with such developments: they were not designed for such a factory. Hence, regulations need to be changed to ensure that production is carried out in accordance with an employee's expectation of privacy and personal autonomy.

However, the relationship between technology and economic institutions works in both directions: institutions also shape technological development. First, because human agency, the ultimate driver of technological change is fundamentally structured by institutions. For instance, the ownership rights of market economies place most investment decisions in the hands of capital owners, who can steer technological development towards their particular interests, unlike a system in which investment decisions are democratically made. Second, institutions can also be explicitly and directly tasked with redirecting technological change, because of the (expected) effects of such change. For instance, some types of technology can be prohibited by law, if their expected effect violates societal norms (as has happened with some types of genetic engineering).

¹ In terms of manufacturing, the Internet of Things relies on the use of cheap digital sensors to digitally monitor every single object in a factory.

2 | Attributes of the digital economy

The key technology behind the digital revolution is the microprocessor. It is the quintessential general-purpose technology, since it can be applied to any type of process that involves information. Microprocessor-based technologies and devices have been developed for the processing, storage and communication of information of all kinds. The possibilities for recombinations and new applications are growing rapidly. The steady reduction in production costs and increase in capabilities of microprocessor-based technologies further leverages their applicability and combinatory possibilities.

In terms of its general applicability, the microprocessor can only be compared with such historical innovations as steam power and electricity. This comparison suggests that it takes a significant amount of time for economic agents to grasp the full possibilities of a new general-purpose technology, and to transform economic processes accordingly. Historically, key innovations often start out as curiosities. They are then slowly applied to the most obvious and directly related industries and activities (such as artificial light in the case of electricity). Only after a significant time lag are they rolled out to all types of industries and activities, reaching their full transformational potential. For instance, the use of steam power in industrial processes required factories to be organised around one or several central large engines. This type of organisation was retained for a period after the introduction of electricity, despite the fact that electricity allowed for the use of smaller motors and therefore a more flexible and efficient modular organisation of production. It took engineers some time to notice this possibility and reorganise factories accordingly; the debate in engineering schools about the relative benefits of the two systems lasted several decades (McAfee and Brynjolfsson, 2017).

The diffusion and application of digital technologies followed a similar process. They appeared most significant firstly in the information and communication technologies (ICT) sector itself, transforming a marginal activity into a massive industry. Digital technologies then spread into related activities, such as media, leisure industries and telecommunications. They are now diffusing to (and transforming) all types of economic activity, including retail, manufacturing, health and education.

The diffusion of digital technologies across all types of economic activity also involves a diffusion of the skills and work methods of the ICT sector itself. In fact, it can sometimes involve a direct colonisation of other types of economic activity by the big players of the ICT industry. This can be seen in the examples of Amazon in

retail, and Google and Facebook in advertising and media.

But how do digital technologies transform economic processes? How does a digital economy differ from an analogue (pre-digital) economy? To a large extent, this is still an open question, since the transformative potential of digital technologies has by no means been exhausted. However, by looking at the sectors and industries where digital technologies have already had a major impact, it might be possible to gauge how digital technologies can transform economic processes.

This report will emphasise four key aspects of digital technologies that – in the author’s view – have significant transformative potential for economic activity:

- flexibility of production
- availability of information
- zero marginal costs
- network effects

Flexibility of production

Until recently, machines applied in any productive process tended to be relatively rigid. The functionality of the machine was physically encoded in its mechanical design: a change of function or operation required a physical change in the design of the machine. With this use of mechanically-assisted production processes (the classic example being the assembly line of Fordism), human operators were the factor providing flexibility to the system, dealing with unforeseen circumstances or giving final touches to the final product, including any necessary customisation. In contrast, however, digitally-enabled production processes are programmed, so the process is not embodied in fixed mechanisms; instead, the process is controlled by algorithms that can be recalibrated as needed. This applies to any type of digitally-enabled production process, whether it be informational (such as administrative processes controlled with database software) or that of physical goods (for instance, an industrial robotic arm that can be programmed to perform different types of operations).

The programmability and algorithmic control of production processes makes them intrinsically much more flexible than previous methods of mechanically-controlled devices. But how far can this flexibility go? Ultimately, it depends on the processing power available to the algorithms. Since it has been exponentially growing in the last few decades, the degree of programmability and flexibility inherent in

digitally controlled processes has also grown at the same rate. Artificial intelligence and deep learning algorithms, for instance, can directly observe their environment and learn whatever tasks they are assigned, with minimal human intervention. Theoretically, therefore, an algorithm could ultimately be as flexible and adaptable as a human being – maybe even more so (even if it is impossible for us to imagine how). This is why the digital revolution could take the automation of labour input in production to the extreme, making human labour redundant. Algorithms that can do anything that a human being can do could make human labour unnecessary.

Availability of information

Digital technologies make information more available at all levels and points of the economic process. This reduces transaction costs, facilitates more complex organisational structures, expands market opportunities and makes location increasingly irrelevant.

Over 80 years ago, British economist Ronald Coase argued that firms exist because some types of transactions are too costly to coordinate by markets (Coase, 1937). Most of the costs of those internalised transactions are, in fact, associated with limited or imperfect information. The increasing accessibility and ubiquity of information associated with digital technologies, therefore, predictably leads to a significant increase in the outsourcing of specific tasks and functions to other companies, even outside the national boundaries. This has deepened and expanded markets to an unprecedented extent, significantly contributing to globalisation. The global value chains of multinational corporations would not be possible without the information and communication capabilities of digital technologies.

In recent years, the combination of instant and almost unlimited availability of information with the principle of algorithmic control, discussed in the previous point, has given rise to an even more radical challenge to the argument of Coase on the boundaries between markets and firms. Digital platforms such as Uber perform some of the functions of markets (providing a space where suppliers and consumers of certain services can meet); however, they also perform some of the functions of firms (coordinating, monitoring and disciplining the supply of services through algorithms). In fact, it is probably correct to say that platforms transcend both markets and firms: they provide functions of both but can do even more than either (they facilitate economic transactions that neither markets nor firms could coordinate).

Defying the distinction between firms and markets, platforms also defy existing forms of labour and market regulations, as attested by some recent court cases in

Europe. As argued in previous chapters, platforms are a new form of economic activity that probably requires new regulations and institutions.

Another important effect of the massive expansion and deepening of markets enabled by digital technologies is the creation of long-tail markets, where the demand for low-market products and services can collectively exceed that of large mainstream goods, subject to effective distribution channels. In massively big markets with near perfect information, there is economic value in the provision of even extremely rare goods or niche services. This is reinforced by the possibilities of customised digitally-enabled production processes, as previously mentioned. The contrast with the mass production technologies of the 20th century is stark: instead of homogeneous national markets for mass-produced goods, digital technologies enable highly specialised long-tail markets on a global scale.

But easier access to digital information can also create winner-take-all markets, in which a single provider of a particular type of good or service tends to concentrate the vast majority of economic activity. The increased level of information on the quality of goods and services available in digital markets removes one of the key traditional advantages of local markets – the trust provided by short-range transactions. If a global online retailer provides detailed and reliable information on a product (including buyers' reviews), secures the transaction and provides fast and real-time trackable delivery, why buy it in the local store at a higher price? Furthermore, the long-tail effect ensures that big online providers will have a massively wider range of products to choose from. Thus, big online global providers are likely to take a very significant share of the market, with potentially damaging effects in terms of market competition and inequality.

Zero marginal costs

The third important aspect of digital technologies concerns digital goods rather than digital technologies directly. Digital goods can be defined as strings of bits (digital information) that have economic value. The generalised use of digital technologies in production tends to make digital goods more central for the economy with low or even zero marginal costs.

In economics, the marginal cost is the increase in total costs associated with the production of an additional unit of good or service: in a textbook competitive market, prices would tend to equal marginal costs. Above marginal costs, producers would increase the supply of the product, bringing down the price; whereas if below marginal costs, the product is not profitable.

Digital goods tend to have zero marginal costs because they are non-rival and infinitely expandable. They are non-rival because their use by someone does not make them less useful for anyone else: a piece of music does

not lose value if someone listens to it, whereas a sandwich loses all its value if someone eats it. They are also infinitely expandable because they can be infinitely reproduced at (virtually) no cost – a digitised piece of music can be freely copied an infinite number of times. Therefore, in a competitive market, non-rival and infinitely expandable goods would have zero marginal costs and therefore a price of zero.

But although the use and reproduction of a digital good has no cost, its production (creation) does. This generates an incentive problem in an economy where production is driven by profit: nobody would produce goods that are costly to produce and that generate no revenue, even if there were a demand for them. In market economies, different institutions have been created to deal with this incentive problem, which applies to any kind of informational good (including ideas, many forms of art and communication), not just digital goods. The most important of these institutions is that of intellectual property rights (IPR).

In principle, IPR give the creators of informational goods monopoly rights over their use and reproduction for a given number of years, backed and enforced by the state. The two most important types of IPR are patents (for inventions with industrial applicability) and copyright (for creative, intellectual and artistic works). Most digital goods are protected by copyright, although patents can also play an important role. For instance, in the case of software, patents are often used to restrict the use of generic ideas or procedures (such as a progress bar for displaying how much of a task has been completed; *The Guardian*, 2005); copyright is used for the particular form in which such ideas are expressed in a commercialised piece of software. It is important to note that despite the similarity in their names, IPR differ significantly from ordinary property rights (OPR) – the socially-enforced rules that determine the use and ownership of goods that are rival and not infinitely expandable. This difference arises from two key factors.

First, OPR defends the rights of the owner of a good, whereas IPR defends the rights of the producer of the good. OPR primarily restrict the capacity of third persons to use a good they do not rightfully own; in contrast, IPR primarily restrict the capacity of the rightful owner of a good to make certain uses of it, such as sharing or reproduction. An unintended effect of this IPR-based restriction is that the enforcement of IPR requires a much more intrusive surveillance, since its focus is on the private use of goods by their rightful owners. In the case of digital goods, cheap and pervasive computers and online tools such as peer-to-peer trackers make the sharing of intellectual property extremely easy. This has led to increasingly intrusive measures of tracking and monitoring the private use of digital goods, such as the controversial use of digital

rights management (DRM) systems for e-books, which scan users' entire libraries and send the information to corporate producers (Electronic Frontier Foundation, 2014).

Second, while OPR does not in itself restrict the potential benefits derived from the use of a good, IPR does. Since digital goods are non-rival and infinitely expandable, their potential use is infinite. For example, a piece of digital music can be shared any number of times without any deterioration; therefore, IPR reduces infinitely the potential use of a good (that is, from infinite to one). This contrasts with OPR, which concerns only those entitled to use the good, but it does not limit its use otherwise: as long as someone eats a sandwich, all its potential benefits are realised. This effect is particularly problematic in the case of patents, which concern inventions with industrial applicability: the restriction of potential uses of an idea may also restrict many potential recombinations and further possible applications of that idea. Patents may incentivise product creation, but they drastically limit recombination, which is one of the most important mechanisms of innovation, as previously discussed. IPR systems may solve the incentive problem of zero marginal costs for digital goods, but at the expense of creating two perhaps bigger issues – the need for intrusive enforcement and the drastic limitation of the potential uses (including combinatorial innovation) of digital goods.

A third, institutionally troubling effect can be added. Because IPR are essentially government-sanctioned monopolies, they immediately create a big incentive for producers to lobby the government in order to strengthen and expand IPR rights, which results in further suboptimal outcomes. Some of the benefits of innovation are deployed in the intrinsically unproductive activity of lobbying, and to the extent that lobbyists are successful, they simply expand rents without any benefit to society (see, for example, Depoorter, 2004).

IPR is not the only institution used for solving the incentive problem of informational goods. Historically, alternative methods such as procurement and patronage have been used as well. The main characteristic of these alternatives is that they 'divorce the ex-ante incentive of an innovator from the ex post stream of rents generated by the innovation' (Quah, 2002, p. 27). In other words, they incentivise innovation/creation directly, by providing grants or awards for innovators/creators, making the resulting digital goods or works generally available in the public domain, thus ensuring their potential benefits are fulfilled, even if authorship is fully recognised. These are the systems most widely used for academic, space, military and basic research and development, which underlie most of the key innovations of the digital revolution (Mazzucato, 2015).

Box 3: The open-source alternative

A more radical alternative to the IPR system, whose origins go back to the very beginning of the digital revolution in the hacking culture of the first software programmers, is the open-source model. This is a model of decentralised production of digital goods (originally software, although it has been extended to many other types of digital goods), where authorship, or rather its contribution, is recognised, but there are explicitly no limitations with respect to the use, reproduction or modification of the good in question. The incentive to contribute to open-source development is reputation rather than money, although that reputation can lead to monetary gains eventually – for instance, through better employment opportunities (Fernández-Macías, 2002).

In the open-source model, the creation of digital goods does not generate any direct monetary benefits for the developer/producer. In this sense, it is a model that on its own cannot entirely replace the IPR system in a market economy. However, it can be easily combined with a patronage or ‘spoils’ system to make it perfectly sustainable, solving the incentive problem, which is how the open-source model has (in practice) been operating since it began.

As previously mentioned, contributions to open-source projects can generate a reputation that can be later monetised by the opportunity to access better jobs. It could therefore be argued that companies hiring respected open-source programmers are subsidising (providing patronage to) open-source development. Many software companies go one step further by explicitly allowing their employees to spend part of their working time on open-source projects. Open-source development is also widely subsidised by public money, since a significant proportion of developers work in universities or publicly funded research centres.

What is clear from the history of open-source software development is that it can be a very powerful system of innovation and work organisation. Despite being entirely voluntary, decentralised and with no (direct) monetary compensation, it has overtaken commercial software development for many types of applications – from operating systems to web servers. The open-source model is extremely interesting for discussions on the wider socioeconomic implications of digital technologies because it shows their enormous transformative potential, if a favourable institutional framework is in place. With instant and pervasive communication, a digitally skilled user-base, and the advantages of a decentralised algorithmic coordination, the possibilities for recombination and innovation can grow in a truly exponential way without generating troubling distributional effects.

Network effects

Digital technologies in economic processes tend to create demand-side economies of scale, or network effects. This means that the value for consumers of many types of digital goods and services increases with the number of users. This effect is typical of communication-related goods and services, a good example being telephony: the more users in the network, the more people can be called, and therefore the more value the service has for the users. A good example of network effects in today’s digital economy is social networks, but it also applies to many other digital goods, services and technologies such as software systems and tools, digital industrial applications (IoT) and industry standards.

Network effects lead to increasing returns in economic activity, favouring market concentration. However, it is important to note that this effect is much stronger than in traditional supply-side economies of scale (typical of Fordism) in which costs tend to decrease with more output because high fixed costs are more diffused. Whereas supply-side economies of scale generally have limits after which additional production implies diminishing returns, the limits of demand-side economies of scale are much larger or even

non-existent, as with peer-to-peer systems used even in large commercial social networks, such as Facebook.

Perhaps most importantly, network effects can create consumer lock-in, because the cost of switching product or service also grows with the size of the network, to the extent that it can effectively make customers entirely dependent on a particular vendor. For instance, it is nearly impossible to use the type of social networking service provided by Facebook without using Facebook itself, simply because (nearly) everyone uses it. Switching to another service provider would require all of a user’s contacts to move simultaneously, which would then require their contacts to move as well.

Other examples of lock-in resulting from network effects is the dominance of Microsoft in the market for desktop operating systems: again, since the value of an operating system also depends on the number of people using it – because we want to be able to collaborate and share information – switching to a different solution provider would involve high costs in terms of learning and require that many other people also switch in order to maintain functionality. This is why the dominance of Microsoft only ended with the appearance of other computing devices beyond the

desktop, such as the technology used in smartphones, in which vendors other than Microsoft have achieved their own lock-in (mostly Google with the Android operating system and, to a lesser extent, Apple's own system).

The very strong concentration effect of demand-side economies of scale tends to create large monopolies, which is a cause for concern. On top of antitrust and competition policies, solutions such as the use of publicly available open standards and interoperability have been proposed. It should be noted that this topic is linked with the problems of IPR, as previously discussed. Large digital companies often resist or try to control open standards and interoperability, claiming that it challenges their profitability and their own IPR. In this respect, the open source systems discussed in Box 3 can provide a viable alternative.

Conclusions

This chapter discussed four key attributes of the digital economy: flexibility of production; readily available information; zero marginal costs; and strong network effects. These attributes can already be observed in the sectors and industries where digital transformation is more advanced; foremost in the IT sector itself, and in the broader communication and leisure industries.

As digital technologies become more widespread and production and work process become more digitised, the attributes listed will also be observed in manufacturing, retail and social services, gradually transforming economic processes in these sectors. Of course, these sectors have their own specific issues and will probably not be entirely reshaped in the image of the IT industry.

3 Implications for work and employment: Three vectors of change

How can the digital revolution transform work and employment? As in the previous chapter, discussing this subject inevitably requires some speculation because the process is still unfolding. However, potential developments can be explored on the basis of how things are already changing in some sectors and industries where the use of digital technologies is more advanced.

On the basis of a review of the literature in this area,² this chapter discusses three vectors of change. These correspond to three broad categories of combined applications of digital technologies in economic processes, with different implications for work and employment.

Automation of work: the replacement of (human) labour input by (digitally-enabled) machine input for some types of tasks within production and distribution processes. Although machine automation predates even the Industrial Revolution, the use of digital technologies allows the algorithmic control of machinery and, therefore, many more possibilities for automation. With digitally enabled machines and artificial intelligence, all kinds of tasks can be potentially automated.

Digitalisation of processes: the use of sensors and rendering devices to translate (parts of) the physical production process into digital information (and vice versa), and thus take advantage of the greatly enhanced possibilities of processing, storage and communication of digital information. This is the main way in which the attributes of the digital economy have spread to sectors and industries beyond ICT, as discussed in the previous chapter.

Coordination by platforms: the use of digital networks to coordinate economic transactions in an algorithmic way.

These three vectors of change rely on digital infrastructures, technologies and skills already widely available in the economy. In that sense, they are clearly attributes of the deployment rather than the installation phase of the digital revolution, according to the schema of Freeman and Pérez presented in the Introduction. They presuppose a certain degree of maturity and

diffusion of digital technologies, and involve the kind of profound transformation of socioeconomic structures that characterises the second phase of technological revolutions. Each of these three vectors of change has the potential to fundamentally transform work and employment in a technological and in a social way. However, each of these vectors has particularly strong effects on one of the domains of work and employment introduced in Box 2 (p. 7): tasks and occupations, working conditions, employment conditions, industrial relations.

Automation has particularly strong implications for the evolution of the types of task input necessary for the production process, and therefore the structure of employment by occupation and sector, as well as the skill levels required. However, it also has direct implications for working conditions (since the automation of certain tasks eliminates some types of work and creates others) and indirect implications for employment conditions and industrial relations (for instance, it can alter the balance of power within workplaces).

The effect of digitalisation is most direct and clear on working conditions, since it involves a change in the environment and nature of work processes. But, for the same reasons, it also involves changes in tasks and occupations, and has an indirect effect on employment conditions and industrial relations.

Finally, platforms represent most directly a change in the social organisation of production, since they are themselves a new type of economic institution: therefore, their most obvious and direct impact is in terms of the conditions and regulation of employment. However, they can also change the division of labour (for instance, they enable a much more detailed breakdown of tasks) and affect industrial relations.

Before looking more in depth at each of the three vectors of change, it must be acknowledged that the distinction between them is (to some extent) more analytical than actual. Very often, digitalisation, automation and platforms will be implemented simultaneously, because there are strong synergies between them. For instance, the use of advanced robots

² For more details, please see the three separate literature reviews carried out by Eurofound in parallel with this report: Peruffo, 2017; Peruffo and Schmidlechner, 2017; Schmidlechner and Peruffo, 2017.

both requires and generates the digitalisation of production – a massive amount of digital data on the robots' environment.

Platforms also require and generate vast amounts of data on the economic processes they coordinate, and they can facilitate automation by breaking up these processes into ever smaller tasks. However, it is useful to distinguish between these three vectors of change because they are distinct processes and have different potential implications. Digitalisation of production can certainly proceed without any automation if every process is transformed into bits, but all labour input still requires human interaction. A good example is the provision of psychological services in a virtual reality environment, with a real psychologist and a real customer behind digital avatars. And automation can take place without platforms.

Automation of work

This report understands automation as the replacement of labour input by machine input for some types of tasks in production and distribution processes. The focus on tasks in this definition emphasises the link between automation and the unfolding of the division of labour.

Automation presupposes a relatively advanced division of labour into highly differentiated tasks, since it is those detailed tasks that can be encoded and implemented by machines. And by replacing labour by machine input (in certain tasks), automation directly alters the division of labour. A significant part of recent research about the implications of automation has focused on how automation has altered the structure of employment – in terms of different categories of task and worker, and how it may alter the employment structure in the future.

It is also important to emphasise that, following the above definition, it is tasks that are automated rather than occupations or jobs. In human labour, tasks very rarely appear in isolation, being instead bundled into occupations or jobs. Consequently, all occupations or jobs involve many different types of task (Fernández-Macías and Bisello, 2016). Until human-level artificial general intelligence (AGI) exists, automation will be always focused on the replacement of particular tasks (or a set of related tasks): technology will never be able to replace all the tasks involved in a particular occupation. Successive rounds of automation may indeed eliminate the entire bundle of tasks associated with a particular occupation, although to date this has been relatively rare. In most cases, automation changes the task content of occupations and perhaps the relative importance of some occupations with respect to others, but it rarely eliminates occupations entirely. A good example is that of how the occupation of bank teller has changed with the introduction of automated teller machines, or ATMs (Bessen, 2015).

Defined in general terms, automation is as old as the use of machinery in production. In the sectors of agriculture and manufacturing, automation has been very significant over the last 200 years, which is why these two sectors nowadays account for a fraction of their historical employment, and yet production has increased in both considerably. What is new about automation in the digital age is that the use of algorithmic control of machinery and digital sensors, with ever-increasing computing power, expands enormously the range of tasks that machines can carry out. The tasks framework proposed (Fernández-Macías and Bisello, 2016) is useful for differentiating those tasks that can, more or less, be automated using digital technologies. Routine tasks (repetitive and standardised, generally as a result of a particular work organisation strategy and a detailed division of labour) are relatively easy to automate. In fact, physical routine tasks had already been automated (to a large extent) in advanced market economies before the digital revolution; today, these are just a marginal category of aggregate labour input (Fernández-Macías and Bisello, 2016, Figure 2). The automation of intellectual routine tasks, which grew with the bureaucratic control of the economy in the first half of the 20th century, is a much more recent phenomenon that has been directly enabled by the digital revolution.

Although it still has some way to go, such change seems inevitable since digital technologies are much more efficient than human labour at routine intellectual tasks, at a much lower cost. According to some authors, it is the decline of these two categories of labour input (routine physical tasks and routine intellectual tasks) that is associated with job polarisation (Autor, 2010); others have argued that it is neither the main driver nor necessarily linked to a decline of mid-skilled jobs (Fernández-Macías and Hurley, 2016). Other types of task are still relatively free from automation, although digital technologies have made considerable progress in this area in recent years.

Physical non-routine tasks that require mostly hand–eye coordination and manual dexterity, typical of many service activities such as cleaning, serving and driving, seemed nearly impossible to automate. However, recent advances in machine learning, sensors and big data are making this prospect increasingly feasible. Soon, the limits of automation for such tasks are more likely to be determined by social norms, and such considerations as regulations, safety concerns and human labour costs, than technological feasibility.

Intellectual non-routine tasks involving creativity, problem-solving and pattern recognition are often considered as the most advanced expression of human activity; even these types of task, however, are becoming increasingly open to automation. Deep learning techniques, such as artificial neural networks, are allowing computers to perform creative,

problem-solving and pattern-recognition tasks that produce results often impossible to distinguish from those arrived at by humans. Whether such digital networks are 'creative' in the same way as humans is a complicated philosophical discussion, beyond the scope of this report. But it is important to realise that the results of such 'creative' work could eventually be sufficiently similar to replace human labour.

Non-routine physical and intellectual tasks now account for a very significant share of the total labour input in advanced market economies; automation of these tasks would therefore significantly affect the employment structure. Such non-routine tasks are more likely to be found at the bottom and the top of the skills distribution (respectively, physical non-routine and intellectual non-routine). Hence, their automation may have a centripetal rather than polarising effect on occupational structures, moving employment towards the middle of the skills spectrum.

There is, however, one big category of tasks which so far has not been discussed. Social tasks that inherently require human interaction – education, health, leisure and social services (routine or non-routine) – are intrinsically more difficult to automate. To the extent that human interaction essentially defines what a task is, by definition machines cannot perform it unless they themselves become indistinguishable from humans, which is still some way in the future, even in the most radical forecasts.³ Following this line of argument, it is plausible that all employment lost by automation would be displaced into social tasks (routine or non-routine).

The image of a future in which robots carry out all physical and intellectual work, while humans occupy themselves in entertaining and looking after each other may not appear so threatening. However, recent advances in human-robot interaction in the areas of caring assistance and companionship suggest that even if they are far from being fully human, social robots may be able to fulfil human needs for some basic types of social interaction and companionship (Breazeal, 2017).

It is important to note that although the automation of social tasks seems unlikely for the foreseeable future, digital technologies can still have a significant effect on the demand for such tasks by increasing very significantly labour productivity. An example in the field of education is the increasing availability of Massive Open Online Courses (MOOCs). These free (or very low-cost) courses available over the internet use online videos and texts, together with interactive exercises and algorithmic monitoring of progress, to provide an alternative to face-to-face education. In this case, no

tasks are automated since a human being (the professor who designed the course and whose lessons have been recorded) still provides the educational service. However, this model can obviously reduce very significantly the demand for human labour in education, which highlights a fundamental issue in the very concept of automation. In the understanding of automation as the replacement of human involvement by machine input, what does 'replacement' actually mean? Even the most advanced industrial robot requires the human intervention to enable it to function. Someone must design and maintain the robot. When something unexpected happens that has not been encoded in the control algorithms, a human operator must take control. In other words, machines cannot entirely replace human labour for the performance of any task, not at least until artificial intelligence comparable with that of humans is developed. If this is the case, what is the difference between a robot and any other tool that increases the productivity of workers? Is it fundamentally erroneous to use the term 'automation'? Instead, should we simply talk about technological changes that increase the productivity of some workers, and therefore reduce the amount of labour input which is necessary for some other types of tasks?

This section on automation cannot be closed without some words about the future. In the recent literature on the subject, there have been several attempts at forecasting how many jobs will disappear in the face of automation, and how fast. These forecasts have generated a lot of attention, as well as anxiety. But is such anxiety justified? Assuming that the current round of automation is not fundamentally different from previous periods of productivity-enhancing technological change, perhaps history can provide some answers.

Previous technological revolutions did reduce the demand for some types of labour. In some cases, this created considerable difficulties for the displaced workers. Perhaps the most dramatic example is the populations displaced by the agricultural revolution and the land enclosures that preceded the Industrial Revolution in the UK (Polanyi, 1957). Over a considerable period of time, displaced surplus labour was absorbed by the expansion of demand in other types of jobs and activities as a result of growing income levels. Agricultural automation continued to dramatically reduce the need for human labour in the sector, with marginally more labour in industry, and most now in services; 200 years ago, the situation was the opposite.

³ In fact, the moment in which machines become indistinguishable from humans would probably be of such evolutionary significance that its potential effects on employment would be irrelevant as the problem for humans would be existential, not economic.

But although history suggests that (in the long term) the employment effects of automation will probably be absorbed by the economy (although in unpredictable ways), it also shows that the large-scale processes of economic restructuring associated with technological revolutions can be (in the short and medium term) socially and politically catastrophic. The terrible conditions of the working class in England during the Industrial Revolution, or the terrifying political consequences of the crisis that followed the Fordist Revolution in the 1930s, testify to that.

Going back to the argument presented in the Introduction, the potential effects of automation on employment and society highlight the need to assess and redesign economic institutions to deal with the social and political tensions that can be expected as a result of the digital revolution.

Digitalisation of processes

The definition of digitalisation used in this report refers to the use of sensors and rendering devices to translate parts of the physical production process into digital information (strings of bits), and vice versa. Sensors are machines that translate analogue into digital information, such as a scanner or digital camera. Rendering devices do the opposite, translating digital into analogue information – for example, a printer. The key advantage of digitalisation is that the processing, storage and communication of digital information is vastly cheaper and more efficient than the analogue equivalent.⁴ By digitalising a process, it can be understood, controlled and manipulated more effectively. To better illustrate this idea, the focus of discussion will turn to three of the key technologies driving the digitalisation of economic processes:

- Internet of Things (IoT)
- 3D printing
- virtual and augmented reality

The processes creating the Internet of Things attach sensors to outputs, inputs, components, materials or tools used in production. These feed into a real-time digital model of the entire process. In turn, this can be analysed, monitored and controlled using algorithms, to an extent that would be impossible in the physical world.

3D printers literally create physical objects from three-dimensional digital models, generally by laying down successive layers of material. Although they are currently mostly used for prototyping and specialised applications, 3D printers have the potential of

transforming all industrial production from beginning to end into a digital process. In such a model, most of the value would reside in the ideas (digital models); the physical objects would have only very limited value.

Finally, virtual reality can move entire economic processes to the digital realm – for example, the provision of some types of face-to-face service. And augmented reality can blend the digital and physical worlds by superimposing digital information over human perception of physical reality.

By digitalising economic processes, these three technologies expand the four attributes of the digital economy previously discussed in Chapter 2 into (potentially) all sectors of the economy: productive flexibility, fast and pervasive information availability, zero marginal costs, and strong network effects. But what are the potential implications for work and employment – specifically, tasks and occupations, working conditions, and employment conditions and industrial relations?

Tasks and occupations

The increased efficiency of digitalised process management and control is likely to be associated with labour-saving productivity growth, especially in areas such as logistics, quality control and administration. Digitalisation facilitates the algorithmic automation of many of those tasks although – as previously discussed – the distinction between automation and labour-saving productivity growth is somewhat artificial.

Another crucial effect of digitalisation, in terms of the division of labour, is the increasing irrelevance of the physical location of labour input in the production process; this could contribute to a further and perhaps final round of globalisation. Richard Baldwin (2016), argued that telepresence (virtual reality technology) and virtual and augmented reality can facilitate the delivery of face-to-face services from any distance, breaking the final boundary that has protected many service activities (and jobs) from globalisation.

Working conditions

The digitalisation of economic processes raises some serious concern for the autonomy and privacy of workers. If every single object in the workplace is a sensor that feeds real-time information to a centralised management algorithm, workers may legitimately feel that their autonomy and privacy are being compromised. The other side of the equation is that improved intelligence and information on work processes can reduce accidents, and dispense with the need for certain isolated, repetitive tasks. For instance,

⁴ Thanks to Moore's Law (processing power for computers will double every two years), it is becoming ever cheaper and more efficient.

quality control largely means repeatedly checking that an item or process meets certain standards, something a sensor can easily do in real time. Digitalisation could also diffuse the methodology and skills of ICT into other sectors of the economy, such as manufacturing, retail and other services.

Employment conditions and industrial relations

Digitalisation makes possible more complex organisational forms of production; it may facilitate the breakdown and subcontracting of an increasing number of tasks, even in traditional production processes. Subcontracting and outsourcing, even crowdsourcing, can result in less favourable conditions of employment for workers in terms of stability, income and working hours. By blurring company boundaries and disrupting union solidarity, such forms of work can also make collective representation more difficult. On the other hand, the digitalisation of all types of economic processes opens them up to alternative methods of collaborative decentralised production, such as those discussed in Box 3 (p. 12). A good example is the ‘makers’ movement of some 3D printing enthusiasts and ‘artisan-hackers’, who use open source licences for digital designs and hardware, and defend a socioeconomic model of cooperative, non-hierarchical and sustainable production (Anderson, 2012).

Coordination by platforms

Platforms are digital networks that coordinate transactions in an algorithmic way. There are two important elements in this definition. First, the network is a structured digital ‘space’ where goods or services can be offered or requested. These online spaces systematically collect, organise and store large amounts of data about the platform users and transactions. Some of these data are fed back to users as records of successful transactions or evaluations, which serve both the purpose of facilitating trust between users and incentivising good behaviour.

The second key element of platforms is a set of algorithms for matching and coordinating transactions in an automated way. The algorithms provide a governance structure to the platforms, incorporating encoded rules as well as automated monitoring and enforcement mechanisms. Platforms are hybrids of markets and firms: the network and algorithmic components of platforms perform the functions of each of those basic economic institutions. Whereas the

structured online space (network) provided by platforms make them similar to markets as spaces where supply and demand can meet, the governing algorithms make them similar to firms as structures of command. The algorithms of platforms are essentially automated forms of management.

What distinguishes platforms from the other two vectors of change previously discussed – automation and digitalisation – is that platforms are at least as much a form of institutional innovation as a form of productive innovation. There is some debate about whether platforms really enable a more efficient organisation of production, or just simply facilitate the exploitation of labour and competitors. From a purely technical perspective, platforms enable a very efficient and transparent distribution of information across a large numbers of users, and algorithmic matching and coordination is much more cost-effective than human coordination.

It has been shown that platforms enable a more efficient use of capacity and resources (Cramer and Krueger, 2016), and facilitate transactions of low economic value that were not previously viable. However, at least part of the success of some well-known platforms can probably be attributed to their success in circumventing regulation in the markets in which they operate, hence profiting from unfair competition. Another reason for their success is the weakened position of workers in such platforms compared with traditional firms. In this sense, the key policy question concerning platforms may be how citizens can benefit from their superior coordinating efficiency while avoiding their potentially negative social outcomes; this question relates to their institutional design and regulation.

Platforms are (to a large extent) a new form of economic activity that does not fit well in existing regulatory frameworks. To ensure that these regulatory frameworks continue to fulfil their social coordination and protection functions, they may need to be adapted. Alternatively, innovative policy approaches could be tried, such as promoting the expansion of different forms of platform governance that provide more desirable social outcomes. For example, open source algorithms – with rules and enforcement mechanisms democratically agreed by the users in peer-to-peer networks – can (in principle) be at least as technically efficient as proprietary commercial models while generating fairer distributional outcomes, and a more even ground for exchange.

Box 4: Classifying platforms

As there are many different types of platforms, it is important to classify them. The definition of platforms used in this report refers to the coordination of economic transactions (involving the exchange of goods and services); it therefore excludes online spaces that are sometimes also considered as platforms – most importantly, social networks. Different authors use different criteria for classifying platforms; key criteria are set out below.

Platform ownership: A key distinction is drawn between privately owned platforms (generally for-profit businesses such as Uber and Airbnb) and platforms commonly owned by their users, such as Blockchain. In most cases, private platforms generate revenue by charging a fee or percentage of the value of each transaction; in some cases, however (especially if transactions are not commercial), they may charge entry fees or generate revenue by displaying ads.

Economic nature of transactions: Both commercial and non-commercial transactions (if the services contracted are paid for or not) may be facilitated through platforms. The category of platforms for non-commercial transactions corresponds most closely with the original idea of the ‘sharing economy’, where goods and services are shared or exchanged rather than purchased. If goods are simply shared without any expectation of reciprocation (beyond recognition) it is a pure gift economy, for example the homestay app Couchsurfing. But if goods are exchanged despite no financial involvement it is a barter economy, such as the service exchange platform Simbi. It should be noted that even if the transactions are non-commercial, the platforms themselves can be for-profit businesses, generally generating revenue by subscription fees or advertisement, as with Couchsurfing.

Content of transactions: The main difference here is between platforms for the exchange of goods (such as eBay and Amazon Marketplace) and platforms for the exchange of services, (including Uber, Airbnb and TaskRabbit). This report focuses on this second type, service platforms. Service platforms can be further subdivided.

- **Online vs local:** commercial service online platforms (such as Amazon Mechanical Turk, or MTurk) correspond to the widely used concept of crowd work; in contrast, commercial platforms providing personal local services (such as TaskRabbit) are often referred to as the ‘gig economy’.
- **Types of tasks involved:** namely physical (Taskrabbit), intellectual (MTurk) and social (Bubble). A distinction can be drawn between platforms aimed at routine repetitive and standardised tasks (such as MTurk) and non-routine tasks which are more complex and/or require creative skills; micro tasks (again MTurk) and larger projects such as the exchange of freelance services (for which Freelancer would be more appropriate) and the associated level of skills required of the worker – low, medium or high.

The heterogeneity of platforms is increasing as they spread across different sectors and activities; this implies that more criteria are needed for a comprehensive classification. Eurofound is currently working on such a detailed classification, specifically aimed at platform work – paid work organised through online platforms.

But what are the potential implications of platforms for work and employment? The most immediate and direct implications of platforms are in employment conditions, since they are a new form of economic organisation that does not fit neatly into the existing categories of dependent employment and self-employment. Concern has been expressed that the situations of some platform workers could combine the worst of both worlds: the more limited social and contractual protection of self-employed workers with the dependence and lack of autonomy of employees. However, the diverse nature of platforms can be associated with very different situations in terms of employment conditions.

The same ambiguity in the classification of platform workers as independent contractors suggests difficulties for collective representation and participation. As independent contractors, platform workers are not entitled to collective bargaining in relation to their platforms or clients; and although unions do represent self-employed workers in some countries, they tend to play a marginal role. Furthermore, the very nature of the tasks and work organisation in platforms makes collective organisation less likely than in traditional companies: the manager is an algorithm, co-workers are independent contractors (potentially geographically dispersed and in competition with each other) and the work is often carried out in isolation or in contact only with the client.

However, there have been some recent examples of mobilisation of platform workers (Tassinari and Maccarrone, 2017), especially in the category of commercial platforms providing personal local services (the gig economy). New forms of online collective organisation are also emerging for crowd workers – for instance, through the use of internet forums and platforms such as Turker Nation (Martin et al, 2014). Such mobilisation may become more frequent as platforms grow, perhaps giving rise to new forms of industrial relations.

The impact of platforms on the division of labour can be substantial. The organisational efficiency of platforms allows for the division of labour into very small tasks; this can result in those tasks being tedious and repetitive (on top of their often being carried out in isolation). These are not ideal psychosocial conditions for work and can often be associated with feelings of alienation. At the same time, some categories of platform work can provide autonomy and flexibility, allowing people who may otherwise find it difficult to participate in certain types of employment. The different categories of platform work are very heterogeneous, and can have very different implications in terms of employment and working conditions.

4 | Commentary

Embarking on a new programme of work for social research can be very exciting but inherently risky, especially if the subject is as broad and ambitious as the implications for work and employment of a technological revolution, which is still unfolding.

The risks comprise unwarranted optimism, undue pessimism and mistargeted insights. It is easy to be overtaken by visions of an ideal world based on the transformative potential of new technologies, which may never be realised. It is equally possible to fall victim to an overly pessimistic viewpoint, assuming the worst possible uses for new technologies, or even attributing humanlike motivations and effects to them, giving rise to fears of robots stealing jobs. It is also easy to overgeneralise, to be inconsistent, and to focus on trivialities while missing important underlying trends; because the subject itself is fascinating (new technologies giving us glimpses of a possible future), even this kind of research may generate some interest. Such research is, however, unlikely to be of much use in helping the democratic process create better policies – ultimately the aim of this report.

This report seeks to minimise the above-cited risks and establish a solid base for Eurofound's research on the implications of the digital age. To that end, this report has looked to provide clear demarcations for the key concepts in this area, and make explicit the assumptions that underlie this research from its inception. Of course, the different research strands that will be carried out within this body of work over the coming years will necessarily require some readjustment of these concepts and assumptions; indeed continuously updating our knowledge about the world on the basis of new evidence is the purpose of research. But interpreting this evidence requires clear concepts and analytical tools, and this report has tried to provide this, for a subject that is continuously evolving.

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The onset of the digital revolution has resulted in technological advances that are constantly evolving. A key element of concern to policymakers is the impact that these changes will have on the world of work and employment. This report reviews the history of the digital revolution to date, placing it in the context of other periods of marked technological advances and examining how technological change interacts with changes in institutions. Digital technologies have considerable disruptive potential, including making production much more flexible and information more readily available. While the information technology sector has been most affected to date, other sectors are rapidly changing with the diffusion of new technology. The report also examines three key vectors of change: automation of work, the incorporation of digital technology into processes, and the coordination of economic transactions through the digital networks known as ‘platforms’.

The European Foundation for the Improvement of Living and Working Conditions (Eurofound) is a tripartite European Union Agency, whose role is to provide knowledge in the area of social, employment and work-related policies. Eurofound was established in 1975 by Council Regulation (EEC) No. 1365/75, to contribute to the planning and design of better living and working conditions in Europe.