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Game-changing technologies: Exploring the impact on the services sector in Europe

Game-changing technologies: Transforming production and employment in Europe

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1. Introduction

Exploring how technology works and how it is applied in a work context can give insights on possible future developments in employment, work organisation and social dialogue practices in workplaces adopting new technologies. Hence, it is important for policymakers and stakeholders to gather early information on the potential implications of the adoption of the technologies and explore the consequences, particularly when they can entail disruptive effects.

Some technologies can become 'game-changing', that is, they have a disruptive effect to critically influence or significantly change outcomes related to existing markets, market actors, established value chains, prevailing legislative and regulatory paradigms, occupations or the working conditions in sectors where they are adopted, amongst others.

The focus of this study is on the services sector in the EU and complements the 'Future of Manufacturing' report[1] by Eurofound (2018). It discusses a selection of technologies which show the potential to substantially transform business activities, work and employment in the services sector in a time horizon of 5-10 years. The technologies were selected based on a thorough review of existing literature and after exchanges and discussions with experts. The five technologies explored in this paper are the following:

- advanced robotics;
- autonomous transport devices;
- blockchain;
- virtual and augmented reality (VR/AR);
- wearable devices.

The services considered in this study include economic activities from wholesale and retail trade (G) to other service activities (S) of the NACE classification (Table 1). Services under this classification show a great diversity and heterogeneity, grouping very different types of activities. The 'service economy' in Europe is strongly interrelated and integrated to all economic activities, from business to business (B2B) professional services to public institutions and citizens. It is the main contributor to growth and employment in the EU, accounting for around two-thirds of both total employment and value added in the EU[2].

Table1: High-level NACE 2.0 classifications

NACE classification	Brief description
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
H	Transportation and storage
I	Accommodation and food service activities
J	Information and communication
K	Financial and insurance activities
L	Real estate activities
M	Professional, scientific, and technical activities

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[1] In this report the five technologies analysed are advanced robotics, Industrial Internet of Things, additive manufacturing, industrial biotechnologies and electric vehicles.

[2] European Semester Thematic Factsheet. European Commission. 22.11.2016
https://ec.europa.eu/info/sites/info/files/european-semester_thematic-factsheet_services_en.pdf

O	Public administration and defence; compulsory social security
P	Education
Q	Human health and social work activities
R	Arts, entertainment, and recreation
S	Other service activities

Economic activities classified as services include a wide variety of tangible and intangible forms, from cleaning to business services and consultancy. Each of these forms can be impacted by the introduction of new technologies and the study will try to differentiate them accordingly. The introduction of information and communication technologies (ICT) and web 2.0 already profoundly disrupted services such as retail, logistics and the music industry at the beginning of the century. This report aims to investigate whether the analysed five technologies have the potential for a similar big impact in the services sector.

After some introductory remarks and background on the importance of the services sector in the economy, the rest of this working paper is structured as follows: Chapter 3 explains the key characteristics of the selected technologies and provides an in-depth overview about the adoption across the services sector in Europe. Chapter 4 deals with the main factors that influence the development of the five technologies object of this study, as well as the associated driving forces and barriers for the adoption. Chapter 5 presents additional challenges for the technologies as those related to the interconnectivity and data collection. Chapter 6 summarises the expected impact of the analysed technologies on the economic processes in the service provision. Chapter 7 analyses the implications of the technologies on several key areas of labour market, such as employment, skills, working conditions and work organisation. To conclude, Chapter 8 brings together the key findings of the study and derives conclusions and reflections about game-changing technologies in the services sector.

2. The European services sector

The services sector represents around 70% of the EU economy both in terms of GDP and employment (Eurostat, 2019). Considering the period 1996-2016 (Figure 1), while employment in industry fell by 5.4%, the services sectors where generally characterised by net job growth.

Figure 1: Share of 10 main economic activities in EU total employment, 1996 and 2016
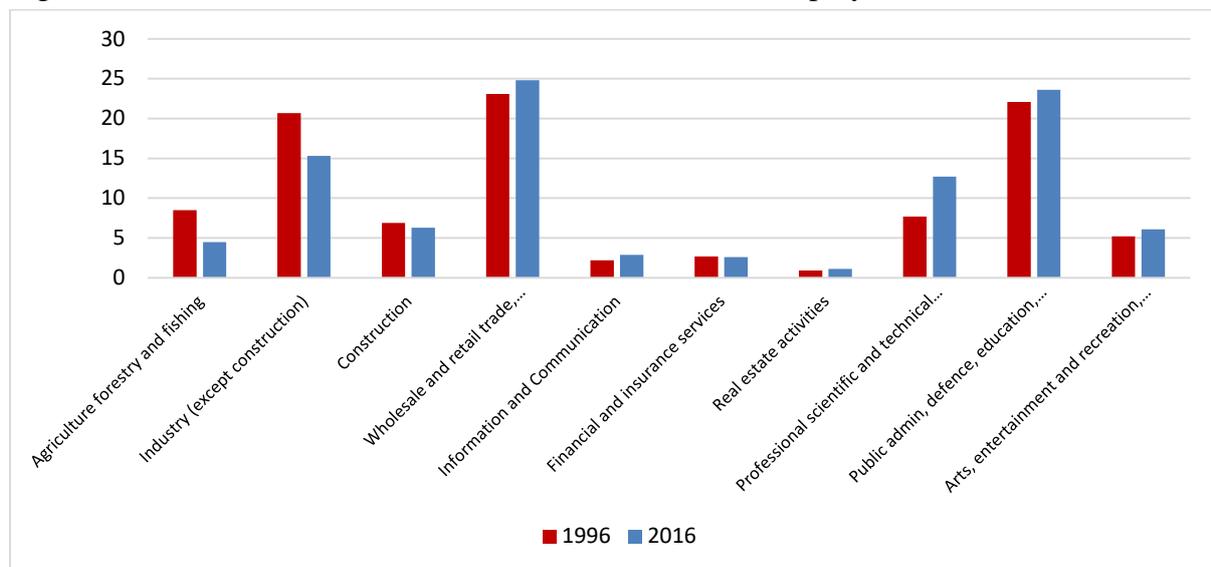
Source: Eurostat (2017)

The services sector as a major source of employment was also visible during the recession years (2008-2013); while losing 7.5 million aggregate net jobs in the EU across all sectors, services grew by 0.25% per annum (Eurofound, 2017). The services sector is labour intensive, given that often there is a certain amount of social interaction required which is found difficult to automate (Osborne and Frey, 2013). Wholesale and retail trade, transport, accommodation and food services were the economic activities providing the most employment in the EU in 2016. Job creation in the services sector is polarised, that is jobs are most often created at the bottom and the top of the wage scale. Among the fastest employment growth occupations, low-skill occupations such as cleaners and helpers in the services to building sector; personal services workers in food and beverages; and personal services workers in other personal services activities accounted for the biggest share of low-paid workers in the EU, while among the fastest growing best paid jobs five ICT professionals occupations are listed (Eurofound, 2017).

Interestingly, the services sector has strong linkages to the manufacturing sector and both show dependencies and mutual effects. Manufacturing provides a multiplier factor for employment creation in services, for example, some services jobs (like engineering, innovation, product design) are directly related to manufacturing (Hauge and Chang, 2019). Additionally, servitisation of manufacturing companies is a longstanding global trend, particularly affecting supply chains. As technology has made some services more tradable, companies can organise and sell services – for example, aftermarket sales – as part of their production design, while integrating them as stable sources of revenues linked to the manufacturing production.

While the features of manufacturing production process have been profoundly analysed by the academic and managerial literature, the same approach to the services sector has been paid less attention to. Apart from the traditional differences found between both sectors – for example, producing physical goods in physical locations in manufacturing versus rather intangible provision of services - the most relevant distinction lies in the participation of the customer in the services production process: while it does not play a role in manufacturing – since the output is mostly based on quality production standards - the *production process* in the services sector entails the participation of customer input, usually based on the impact of the service itself (Agya and Singh, 2014).

3. The analysed game-changing technologies

Understanding how a technology is used and what are its applications allows to speculate about the potential implications for workers, businesses and society. Based on pilot projects and case examples, of its introduction on workers and work organisation, the changes which could occur in terms of workforce numbers, type of contracts, working hours or skills required. The more specific the technology, the easier it is to isolate and describe its expected impacts. The five technologies analysed in this report have been selected on the basis of literature reviews and on three scoping consultations with stakeholders that included cross-sector technology and socioeconomic experts. The definitions used for the five technologies can be found in Table 2.

Table 2: Description of the game-changing technologies explored in this report

Technology area	Brief description
Advanced robotics	The term service robots is normatively understood as any robotics applications other than for manufacturing (the ISO definition being robots 'that performs useful tasks for humans or equipment excluding industrial automation applications' [ISO 8373: 2012]). Advanced robotics refers to the improvements in machine dexterity and the machine's ability to interact with its environment, as a result of which robots can be engaged in tasks that go beyond repetitive, discrete motions (see Grant, 2012, for further details).
Autonomous	Autonomous transport devices are vehicles able to sense their

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Technology area	Brief description
transport devices	environment and navigate it without human input (see Rohr et al, 2016, for further details).
Blockchain	Blockchain technology is one of the most well-known uses of distributed ledger[3] technologies (DLT), in which the 'ledger' comprises 'blocks' of transactions, and it is the technology that underlies cryptocurrencies such as Bitcoin (Deshpande et al, 2017). In a distributed ledger information about a transaction is recorded in an immutable way onto the system and the information is simultaneously held by all the 'participants'(nodes) in the system without the need of a central authority which certifies that the transaction happened.
Virtual/augmented reality (VR/AR)	VR is a computer-generated scenario that simulates a real-world experience (Steuer, 1992). AR combines real-world experience with computer-generated content (Azuma, 1997).
Wearable devices	Wearable devices are technologies comprised of an ensemble of electronics, software and sensors, which are designed to be worn on the body (Billinghurst and Starner, 1999).

When looking at commonalities and differences among these technologies it is useful to apply Eurofound's approach to the socioeconomic impact of digital technologies, which identifies three vectors of change: automation, digitisation and coordination by platforms (Eurofound, 2018). Automation refers to the replacement of (human) labour input by machine input for some types of tasks within production and distribution processes; digitisation is the use of sensors and rendering devices to translate (parts of) the physical production process into digital information (and vice versa); coordination by platforms refers to the use of digital networks to coordinate economic transactions in an algorithmic way.

Bearing in mind that these vectors of digital change are an analytical tool and that reality often sees overlaps and interaction between and among technologies (for example, an autonomous vehicle can be classified both as a robot and as a cluster of sensors), it is still a convenient way of classifying technologies to glean potential impact on tasks and work (Figure 3). Furthermore, the combinatorial ability of some technologies analysed plays an important role by upgrading the technical capacities and can open the way to applications in fields different from the one the technologies were born into.

Table 3: Vectors of digital change and interrelated technologies

Automation	Digitisation	Coordination by platforms
Autonomous transport devices	Virtual/augmented reality	
Advanced robotics	Wearable devices	Blockchain

Advanced robotics can be grouped with autonomous devices under the automation vector since their ultimate aim is substituting human labour input (robots or automated software performing the task(s) of a worker and the vehicle driving itself). Digitisation of processes encompasses the main

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[3] A distributed ledger is a digital ledger (a computer file used for recording and tracking transactions) that stores cryptographically authenticated information on a network of machines, whereby changes to the ledger are reflected simultaneously for all holders of the ledger.

characteristic of wearable devices, virtual reality and augmented reality; the three technologies use digitised information to:

- create virtual environments;
- augment the knowledge of a visual scene by superimposing information;
- gather data about people and/or processes by 'attaching' sensors to them.

Blockchain is mostly grouped under the vector of coordination by platforms because the transactions are enabled by algorithmic operations and the distributed ledgers can record transactions according to a set of rules which do not require human intervention after their initial set-up. It could be argued that blockchain embeds also elements of automation and substitution of human input as well as it may be grouped in the digitisation cluster, since all the operations take place digitally (transactions are transformed into bytes and exchanges of cryptocurrencies or smart contracts take place in cyberspace); however, for the purpose of this analysis the most prominent vector is being used.

Keeping in mind the current debate (as of 2019) on technical change, the discussion cannot avoid mentioning Artificial Intelligence (AI). Although there are many definitions[4], AI can be deemed as a general purpose technology (GPT) which enables and supports the application of many others (Brynjolfsson et al, 2017). In that sense, it can be viewed as fields of the same discipline approaching in different degrees and in different ways intelligent behaviour applied to hardware (robotics) or software. Accordingly, the underlying presence of AI has been taken into consideration while looking at the five selected technologies but not analysed as a stand-alone separate application. Furthermore, acknowledging that *general AI* 'is always 30 years away' (Greenfield, 2017), that is, as of 2019, experts have always set the breakthrough happening far away in time, this paper uses the definition of *narrow AI* which enables, through machine learning and deep learning, the extraction of information from an enormous amount of data and generation of new value based on models built with those data. Narrow AI is applied to all the five technologies. For example, AI can be used to analyse data or to maintain infrastructure used in blockchain or create software for AR/VR. Another transversal technology, Internet of Things (IoT), enables wearable devices, advanced robotics and autonomous vehicles.

The selected technologies have in common the potential of disrupting the services sector, but not all in the same way nor to the same extent. Essentially, what is perceived as disruptive in one sector might have been common practice in another for a number of years. Causes for this heterogeneity are various; among others, service peculiarities, R&D and investment costs, regulation constraints and availability of technology.

4. An uneven applicability in the services sector

4.1. Applications of technologies with prevalence of automation effects

The different technologies are at different stages of technological maturity and uneven degree of adoption across the individual services sectors. From a technological perspective, more development and more testing is still needed, for example, on autonomous transport devices, therefore calling for more investment to unleash the full potential of these technologies in the provision of services.

Advanced robotics refers to machines that can replace labour input with a relatively high degree of autonomy. Although there are no standard definitions, the main difference between 'traditional' and advanced robots concerns the range of tasks they can perform autonomously. Whereas most existing robots, such as those typically used in manufacturing, are generally restricted to physical tasks with a high degree of repetitiveness and standardisation, advanced robots are able to do some information

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[4] The Joint Research Centre (European Commission) defines AI as 'any machine or algorithm that is capable of observing its environment, learning, and based on the knowledge and experience gained, take intelligent actions or propose decisions' (Joint Research Centre, 2019).

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processing and even social interaction tasks in unstructured environments, which make them fit for service applications.

Advanced robotics may be considered to have the widest and cross-cutting applicability across services at the time of writing. The heterogeneous nature of tasks performed as part of the services sector shapes, and to some extent limits, the design and adoption of service robotics. These devices must work many times in unstructured spaces and, depending on the service, show nearly human social and communication skills, which require the design of human-machine interfaces. Despite these limitations, progress made in research and engineering is fast and a widespread use of robotics is already taking place in logistics, civil and public services and health care, as shown in Table 3.

The use of robotics in the services sector will speed up along with technological advancements in areas such as navigation, sensors and the associated software, including AI and natural language processing (NLP). Advances in related technologies, such as the Internet of Things (IoT) and autonomous machine learning, may enable further advanced robot applications, including the design of fully autonomous systems of interacting robots. However, it must be acknowledged that the widespread use of advanced robots for service provision remains a speculation driven by recent impressive advances in AI. Even the most advanced existing robots are restricted to relatively routine tasks of a physical nature, so that the potential for a generalised automation in services remains low at the moment.

Autonomous transport devices can be understood as a particular case of advanced robotics, in the sense that they involve the automation of a specific set of tasks which are still quite prevalent in the services sector and which involves the control and navigation of transport devices. Compared to other types of service activity, driving may be more susceptible to automation because it involves limited social interaction and to some extent relatively restricted and predefined conditions, although with some degree of uncertainty and unstructured environments. However, the technology is still not fully operational for highly unpredictable or complex situations such as city traffic. After initially very optimistic assessments of the possibility of full automation of most vehicles in a near future, a more cautious and incremental approach (assuming only partial automation or the use of automation technologies for aiding rather than fully automating driving activity) seems to be taking hold.

Although automation already exists in various degrees in a variety of transport vehicles, experts agree that full automation in autonomous road cars or trucks will still take considerably more time to be adopted. In turn, the adoption of self-driving vehicles will require the combination of different technologies (cameras, radar, V2I, V2V[5]) and a massive investment in sensor-embedded infrastructure and environment (road signs, traffic lights and travel lane markings, etc.) as well as the capacity to manage, store and process real-time data (adoption of 5G net). Even though predictions vary, these technological requirements suggest that the adoption of autonomous road transport vehicles will still need long time to be operative, while a transition period of coexisting traditional and semi-autonomous vehicles is the plausible scenario.

Autonomous transport devices may change the way people travel across cities or countries and the business models in some services. In this sense, the adoption of autonomous transport devices has also implications for a wide array of services sectors. Nevertheless, the transport sector for both passenger and freight is the most directly impacted by the rise of autonomous transport devices. Road vehicles, but also drones, delivery bots, trains and waterborne devices might be automated and could become autonomous.

Indirectly, autonomous transport devices could also affect non-transport sectors where the movement of goods and people play an important role. Any business service activity that employs drivers or manages a fleet or large supply chain could also be impacted by this technology.

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[5] Vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) allow vehicles to communicate and relay data in real time analysing the surrounding area in order to drive safely.

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The logistics sector using robotics in warehousing and the postal service are and will be heavily impacted by autonomous transport devices. Drones are expected to play an important role in automating the 'first mile'[6] and 'last mile' of trips (Amazon Prime Air), as well as other sectors that rely significantly on supply chains, such as food distribution. Drones equipped with cameras and sensors can also be applied to marketing and advertising industries as well as to support public services.

Insurance would be another non-transport-related sector seriously affected by (indirect) changes needed to address regulatory frameworks about civil liability and insurance for autonomous vehicles.

4.2. Applications of technologies with prevalence of digitisation effects

Due to their rather product-oriented nature, there could be less room for implementation of VR/AR and wearable technologies in some services activities. Nevertheless, these technologies can reduce enormously the physical presence constraint typical of services, thus facilitating the remote provision of many additional types of services. For example, VR has a huge potential to be applied across services in particularly in training activities. As of 2019, **VR** development is closely related to the gaming and entertainment sector, but its diffusion is expected in other services such as real estate, design and prototyping, sales and marketing and others. VR-based immersive experiences are used in certain activities such as defense and civil uses, for example for training police and military services or in the training of pilots, reducing costs by using flight simulation systems in the aviation industry.

In project design and engineering, VR may facilitate products design, even in real time, by virtual prototyping through the remote collaboration of various teams.

AR lends itself to implementation on smartphones and other portable devices, making this technology very interesting for businesses wanting to reach a large consumer base and at the same time reducing operational costs and improving marketing by engaging customers more effectively. AR can blend reality and digital interactions, which could support some types of face-to-face services from a distance. AR can also support surgery planning procedures and better facilitate remote collaboration involving doctors and other specialists in different locations by providing real-time visual feedback.

In the tourism sector, VR/AR products are being used in museums and other cultural heritage sites to enrich visitors' experiences. It has been suggested that the use of VR could lead to an increase in the ability to empathise with victims of post traumatic disorder by allowing people and carers to virtually experience what happens, for example, to civilians in the middle of a battle or to epilepsy sufferers.

Wearable devices have a range of applications in the services sectors. In the healthcare services, wearable devices may be applied for remote healthcare monitoring by gathering physiological and biomedical data of patients. This continuous monitoring of patients' vital signs – for example, smart patches that continuously monitor blood pressure through at-home monitoring facilitated by wearable devices could facilitate early diagnosis in the healthcare service.

One of the most widespread applications of wearable devices is aimed at performance enhancement as well as physical protection. Wearable devices are used by soldiers, police, disaster relief workers, fire service personnel and paramedics to monitor their safety in potentially dangerous environments. Furthermore, wearable applications are used to track movements and localisation (firefighters, field medical personnel) in emergency situations as well as to provide remote real-time data and communication support and feedback.

Some wearable devices are designed to augment human capabilities and to overcome physical limitations, for example, fatigue or the need of more strength and endurance. The use of smart gloves (increasing work speed) or exoskeletons is growing, as far as the former should not be only 'worn' and designed to support the wearer, but also to collect and process data about the wearer or the wearer's environment.

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[6] The 'first mile' in transportation planning and supply chain management refers to the first mile in the journey or movement of people and goods from their departure point in the home or their business premises to the transportation hub. See Goodman (2005) and Zax (2011).

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In the transport sector, wearable devices are being developed to promote safer driving and flying and to provide navigation or threat information to the driver or pilot. In retail, marketing and advertising services, wearable devices will allow data integration between consumers' homes, on-the-go and in-store experiences.

4.3. Blockchain applications

The financial and insurance services are obvious recipients of blockchain applications, for example, for digital identity verification, bookkeeping, recording and safekeeping of assets, collection and compilation of data for reporting and regulatory compliance. Many of these processes can be automated, increasing system resilience, reducing transaction risk by rendering transactions immediate; enabling 24-hour operations (for example, for stock trading); and otherwise reduce operational costs for business by automating backroom processes. Blockchain technologies involve a digitisation and platformisation of contracts, allowing a decentralised and automated registration and verification system for potentially all kinds of transactions and contracts. The most direct applicability and potential impact of blockchain technologies is in the business and public administration sectors, although by allowing decentralised and platform-based coordination for all kinds of service transactions and contracts, it could potentially transform in more radical ways the whole service sector, facilitating new forms of service provision and coordination.

Being a general-purpose technology, blockchain may enable further development in other areas, such as advanced IoT applications. However, blockchain may have disruptive effects across economic activities in the services sector where functionalities related to the verification of identities, using private keys unique to individuals, are needed, for example secure storage and sharing of documents or timestamping. The effectively immutable nature of certain blockchain designs could enable the timestamping of certain information to verify first use (for example, patents or intellectual property claims) and to provide a verified record of activity (for example, to meet regulatory or reporting requirements). Furthermore, blockchain technology may serve to encode education certificates, professional qualifications and lifelong learning records on a shared ledger, thus allowing prospective employers or other stakeholders to verify qualifications without the need to rely on paper or contacting the issuing institution.

In the retail sector and the supply chain management, the blockchain ability to keep a secure and immutable record of data increases the transparency of goods tracking, provenance and ownership, reducing the vulnerability to theft and double-accounting. Similarly, it may be applied to the health sector for its potential use in storing and sharing medical records, the tracking of prescriptions or the automated reporting of clinical trial protocols and results, among other applications. Nevertheless, ethical concerns were raised about the privacy implications.

The potential applications of blockchain in the so-called 'smart contracts' has been praised. The automated nature of such contracts, in which the terms are enforced by algorithms rather than intermediaries, has found supporters outside the cryptocurrencies field: self-executing codes move into action once the requested criteria are fulfilled, automatically adding to information already stored on the ledger, for example, when transferring the ownership of a token.

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Sector	Autonomous transport devices	Advanced robotics	VR/AR	Wearable devices	Blockchain
Wholesale and retail trade	Car dealers; vehicle maintenance	Public relations	Virtual sales and online trading; marketing; maintenance work in mechanic services	Marketing, advertising and purchasing decisions; smart clothing	Ownership tracking and supply chain management
Transportation and storage (logistics and warehousing)	Freight (road, maritime, railway) and passengers transport (taxis, busses); postal service; logistics: storing and last-mile delivering	Customer services robots; personal services; warehouse storage; order-picking and delivery; adaptive warehouse organisation	Tracking systems in warehouses and logistics	Warehousing; increasing safety in transport	Platforms
Accommodation and food service activities		Cleaning robots	Tourism		Indirectly
Financial and insurance activities	Vehicle insurance	Public relations	Virtual sales and online trading		Coordinated bookkeeping; recording and storing assets; automated regulatory compliance; automated process and reduction of transaction risks
Real estate activities	Parking garages, real estate agents		Virtual and 3D simulation		
Professional services			Psychological treatments and personal care related-services; architecture and urban planning	Sports sector; psychological care	Smart contracts replacing business services (legal, financial, etc.); new means of internal data management

Sector	Autonomous transport devices	Advanced robotics	VR/AR	Wearable devices	Blockchain
Public administration, civil services and defence	Public services using drones	Personal care robots; inspection, monitoring and maintenance robots in civil services; police and military services operating in hazardous environments; automated devices for emergency situations	Training police and military services; training of pilots	Safety and monitoring in emergency services; police and military services	Timestamping for intellectual property rights; increasing transparency in delivering public services; reducing tax fraud by automating tax collection
Education and training		Scientific investigation, biomedical robots for laboratories research robots	Driving schools; supporting overall education and training processes and activities		Encoding training and educational qualifications; issuing and verifying academic records; managing institutional accreditation standards
Human health and social work activities	Autonomous mobile delivery robots	Surgery, rehabilitation and delivery robots; therapeutic	AR supporting surgery or diagnosis; AR facilitating remote collaboration by providing real-time visual feedback	Remote health monitoring, including workplaces	Storing and sharing medical records; automated reporting of clinical trial protocols and results; tracking of prescriptions
Arts, entertainment and recreation	Drones used for videography		Touristic and cultural sites		

Source: Own elaboration based on Eurofound (2019a), Eurofound (2019b), Eurofound (2019c), Eurofound (2019d), Eurofound (2019e)

Box 1. Adoption of game-changing technologies in public services

Public sector activities where advanced technologies are already applied are mainly emergency and rescue, training and urban planning. In emergency and rescue, advanced robots which can autonomously move are used in at-risk settings such as earthquake areas or inside sophisticated machinery, for example to clean it.

Police forces can use wearable devices such as smart cameras which allow to record actions of both police and people involved in a confrontation. Police forces are also trialling augmented reality in the form of smart glasses which can be worn while investigating a crime scene; this way an investigator could give remote instructions on what items need to be examined or collected. Both cameras and smart glasses, similarly to other domains of application, touch upon monitoring of workers' actions and trade union observed that clear guidelines need to be issued on how recordings are treated (for example when does an agent start recording or the fact that recordings could be used against the police in a court case).

Augmented reality is also being used to shape cities' urban plans: in Sweden the municipality of Växjö has prepared augmented reality scenarios which can be activated by citizens on their smartphones. When a citizen is in an area where the municipalities want to regenerate or make changes to, citizens can visualise through augmented reality how that particular area would look like and give their feedback via the AR application.

In the Dutch municipality of Zuidhorn blockchain is used in a pilot study that is offering services for children in the form of vouchers (Gemeente Zuidhoorn, 2017). The Child Package (kindpakket) offers benefits in-cash for different needs and services and is intended for children living in poverty. Using the blockchain technology, recipients of the child package can handle payments in a simplified manner. The municipality covers the actual cost of the purchased item/service (van der Beek, 2018).

5. Factors influencing market adoption

Technology adoption by businesses and public organisations is influenced by a number of factors that, in turn, may work as drivers or obstacles, depending on each specific case. Undoubtedly, being part of an innovative and competitive environment constitutes a precondition to boost technological change. In that sense, innovation hubs as well as the possibility to grow in technological 'ecosystems', that is, in settings where businesses, research networks and government policies favour digital change constitute a driver for adoption.

Nevertheless, there are some elements which may slow down or accelerate the adoption of game-changing technologies in the services sector. Financial considerations – and constrains - play an important role, although they can be balanced by the expectations on return and profitability. Overcoming technical difficulties to reach market production and economy of scale can be challenging, along with the need to get the right infrastructure – for example, 5G networks favouring fast connectivity – widely available. Well-established regulatory and institutional frameworks also enable the adoption, whilst prevent or delay a proper implementation otherwise.

Furthermore, social acceptance as a result of trust in the technology – or lack thereof - can influence the adoption. For example, psychological barriers should not be underestimated, like the low levels of consumer trust in self-driving vehicles. To this extent, citizenship controversies about privacy and ethical issues or the environmental effects have gained room in the public domain.

In the following section, some key influencing factors for the adoption of the technologies are discussed, on the understanding, however, that some factors do not act isolated; on the contrary, they might interact with each other. Nevertheless, Table 3 shows different factors which may act as potential drivers and barriers and influence the adoption of the five technologies analysed across the services sector.

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5.1. Financial considerations and business expectations

The main driver for implementation and, therefore, for the investment in R&D will come from the business expectations regarding revenues and profits generated in the medium term. Even though there may not yet be yet a well-defined market or evident demand for the adoption of some technologies analysed (VR/AR, blockchain, wearable devices), the expectation of gaining competitive advantage by positioning early in the market is a powerful driver. Even though competitiveness is related to a relative market share – irrespective of the number of customers or users – the early adoption of game-changing technologies may be particularly interesting in the services sector, in which the market target of some activities (such as retail, accommodation) addresses a large number of potential customers. In contrast, it has been suggested that the cost of changing conventional vehicles to acquire the new self-driving cars can act as a barrier which may slow adoption.

The availability of financial resources for both development and adoption of the technology is a key element for commercialisation. Some of the analysed technologies, like advanced robotics, wearables or VR/AR, require high initial investments as well as continuous funds for maintenance of equipment and (data) infrastructure. This, in combination with the rather high level of uncertainty as regards whether and when a satisfying return-on-investment can be realised, can constitute an important barrier for companies to engage with game-changing technologies. Considering that a large proportion of services companies are SMEs which traditionally identify access to finance as a key challenge for their business activity, this aspect should not be neglected.

5.2. Human health and safety environments

Most of these technologies can contribute to a general improvement in human safety, especially in the provision of dangerous services. This positive expectation is one of the driving forces in the adoption of advanced robotics and in the future also likely for autonomous transport devices with regard to road safety. Similarly, wearable devices such as smart gloves can offer direct physical protection and VR/AR applications contribute to improve workers' safety through training programmes (VR) addressing high-risk jobs and hazardous situations using simulated environments or direct real time guidance (AR).

Despite the expectations mentioned above, some potential safety issues have been raised. Services-specific risks of robots in areas such as healthcare, education, professional services and transport need to be further researched, since growing human-robot interaction is envisaged. For example, the ISO standard for personal care robots (ISO 13482:2014) identifies risks such as ergonomics of human-robot interaction and cognitive load, as well as concerns about physical safety relating to operation in this environment. Additionally, according to research in the field of Human Computer Interaction (HCI)[7], risks would emerge when workers or consumers assume that the machine has human-like perception, thus overestimating its ability of reading and reacting to the surrounding environment (Eurofound, 2019e).

Although wearable devices are often designed to increase personnel safety, some unintended impacts could, paradoxically, decrease personal safety. It has been reported that wearable devices display that project messages and information in drivers' or pilots' line of vision could distract them from driving with information and tasks and thus offsetting the potential safety benefits. Similarly, potential additional risks related to driving security and personal safety may emerge during the transition period in which autonomous transport vehicles coexist around conventional vehicles driven by humans.

Not surprisingly, the risks for human health derived from human-robot interaction in the workplace have received more attention from the physical and psychosocial perspective. Depending on the way that robotics is deployed, potential negative effects on workers' health may emerge, although the psychological impact of working alongside robots is currently unknown. This lack of knowledge

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[7] HCI focusses on both the improvement of the capacity of robots to read human emotions and on the ability of humans to interpret machines' movements, both for robotics and autonomous transport devices the use of 'eyes' to indicate movement direction and mimic facial expression.

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reinforces the need to research on the consequences of introducing robotics from an anticipatory and cautionary approach similar to the one used in the environmental policy: no robot should be implemented at the workplace or in the provision of services until an impact assessment has been properly made. In any case, close monitoring of the long-term effects of robot adoption is crucial considering the heterogeneity of the services sector.

For VR and AR, potential risks of motion sickness and nausea has been occasionally reported, however there is no conclusive evidence of this effect on workers' health.

5.3. Regulatory frameworks and standardisation

The development of technology can require changes of regulatory frameworks which deal with issues created by new processes and procedures. The adoption of autonomous transport vehicles will require a set of new norms framing the coexistence between conventional vehicles and automated ones, at least during the transition period likely to occur. Robots working in public spaces or delivering personal services may require the establishment of new rules or protocols or the adaptation of existing legislation, for example the EU Machinery Directive[8] dealing with minimum safety standard for machine products in Europe, which is unlikely to cover the last-generation robots.

Liability is another challenge that needs to be addressed, as the current rules assume that when the vehicle is used on the road, there is a human driver on board. In case an accident occurs, it should be clear who is responsible for any damage. This might require changes in legislation, traffic rules and insurance policies (EPRS, 2019).

In the case of blockchain, regulatory change could be required regarding both system design (for example, the way in which data are stored on the blockchain) and specific applications, such as the legal status and enforceability of smart contracts. In that sense, the European Committee for Standardisation (CEN) has published an EU White Paper on Blockchain standardisation[9].

5.4. Sectoral and technical features

Sectoral features constitute driving forces for the adoption of technologies in each specific service activity. Robots' purpose shape the robot's design; for example, some safety robots have tubular or snake-like shapes which make them adaptable to carrying out dangerous activities in restricted spaces; humanoid cobots are more likely to be applied in some healthcare sector activities where patient interaction is required. In turn, wearable devices are properly tailored to be adopted into specific services activities, for example as activity trackers or health monitoring devices.

Technical constrains also apply to varying degrees with regard to the dependency on the connectivity and data flow infrastructure in which some technologies operate; this is particularly evident in services activities where the ability to capture and analyse information collected in real time is essential. In this regard, low-speed internet or bandwidth-poor connectivity to Wi-Fi, 4G, or 5G, can act as barriers to the adoption of these technologies.

For example, wearable devices as well as VR/AR need to leverage interoperability (see Chapter 5) across data systems and achieve high-velocity data exchanges to fully exploit the advantages deriving from their use. The adoption of advanced robotics may face challenges when it comes to work in services environments. As of 2019, a key constraint of advanced robotics in services is the ability to work in unstructured settings and respond to unexpected scenarios. In the short term, this may hinder the adoption of robots to personal care services and other services provided in less structured environments, as open public spaces or busy public environment, such as a tourism sites or shopping

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[8] Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast) https://ec.europa.eu/growth/sectors/mechanical-engineering/machinery_en

[9] Recommendations for Successful Adoption in Europe of Emerging Technical Standards on Distributed Ledger/Blockchain Technologies: https://www.cencenelec.eu/news/brief_news/Pages/TN-2018-085.aspx

centres. Social interaction, that is, robots' capacity to interact with the public - potentially having to deal with children and animals - is still a pending issue in the services sector.

A second challenge for the adoption of robotics has been identified in the need to technically improve a range of tasks and functions such as picking, handling, dexterity, manipulation and transporting.

Wearable devices' technological limitations which could delay the adoption are the battery life duration, the lack of comfort of wear (in terms of temperature and weight), or weaknesses in the materials used. Another limitation could be represented by the lack of accuracy; some fitness monitoring devices have not been marketed as medical devices due to inaccurate heart rate measurements.

Apart from technical features, there are concerns regarding infrastructural gaps in the adoption of autonomous transport vehicles. Despite the progress made in autonomous vehicles and the efforts made in the industry, a relatively long transition period, where conventional vehicles and autonomous transport devices share the same roadways, is envisaged. This learning process period will come risks due to the need to adapt driving patterns – in conventional vehicles.

5.5. Trust, cultural acceptance and resistance

The adoption of new technologies depends on the level of trust that users have in the technology meaning that there needs to be trust in the companies promoting the product and in the way the product works. For workers and employers there needs to be a common understanding of the technology applications and the use of the data deriving from their use. If workers think that, for example, the data collected through wearable devices goes beyond the agreed scope thus infringing their privacy, they might refuse to use the technology. Data protection regulations, such as the EU General Data Protection Regulation (GDPR), need to be fully operational and duly implemented at workplace level in the services sectors. In the sports world, specifically in soccer, there is a debate on the ownership of players' data which currently belong to clubs and not to individuals (Eurofound, 2019d). Can these data be sold when the player changes team? This debate can be applied to other workplaces and is also an issue in platform work, where workers would like to have ownership of their data and be able to carry on, independently of the platform, past performance indicators.

Public trust is an issue for AR applications, for example smart glasses used in a public setting where people's movements and whereabouts are being recorded. While use of these in public spaces never took hold (as it happened for the google glasses which also caused concerns about copyright infringements) police forces have started to explore the potential of devices such as bodycams to record agents' actions and provide evidence of assaults against them. The issue of human-machine interaction is not limited to reading the behaviour of the machine for safety purposes, but also relates to the acceptance towards certain types of tasks being carried out by machines instead of humans. The often-discussed cultural barrier that western countries seem to have on the use of robots to care for patients seems not to be an issue in Japan. Given the demographic trend of an ageing population the issue of who or what performs certain tasks involving people's care might be a challenge that EU countries need to address. Especially in the personal services sphere, the use of a machine could lead to a detached view of people when tasks are performed remotely (advanced robotics, telepresence) resulting in a desensitisation of human remote operators.

Table 5: Example of factors influencing the adoption of the five technologies across the services sector

	Autonomous vehicles	Advanced robotics	Wearable devices	VR/AR	Blockchain
General drivers					
Increasing efficiency	Productivity gains due to automation by improving performance and reducing risks of error	- Enabling 24/7 monitoring and inspection capability - Integration with data analysis capabilities - Increase in quality and regularity of monitoring data by lower costs		- Applicability to training processes and reducing costs - Provision of services through remote virtual connections	Potential to increase productivity and system resilience by the automation of organisation processes; processing and verification of data more efficient or partially automated
Improving safety	Safe driving	- Replacing dangerous tasks for humans by operating in hostile environments and hazardous situations - General reduction of safety risks for workers		Improving workers' safety and reducing risks through training processes	
Potential interoperability	Coordination and convergence of data and software Combination with AI and IoT infrastructure systems using 5G and other				
Sector-specific drivers	- Fuel and energy efficiency		Reduced cost of underpinning software and hardware	Growth in the gaming and entertainment industry; increased availability and use of mobile devices; increased availability and diversity of VR/AR digital content	Application to across services
Predominant barriers					
Regulatory constrains	Regulatory framework to be adjusted or created, including safety standards				Unclear regulatory framework and governance system
Technological and infrastructure limitations	Overall physical and digital infrastructure in road transport	- Fully automated processes (picking, handling, transporting) still in early stage of development - Adaptation of work environment	- Poor connectivity to the web and limited access to streaming content - Improving quality of materials, increase in battery life and comfort of wear	System infrastructure (including devices, network connectivity and other physical infrastructure)	Complexity; complex governance and compliance arrangements for multi-party ledgers; issues related to performance and scalability; current lack of standardisation; the high energy use of some public blockchain designs
Uncertainty on	High Capital Expenditure (capex) expected for financing the adoption with long-term return		Financial cost required in equipment and data infrastructure, as well as the maintenance		Controversy and contentious debates on energy costs increased by mining

development costs				
Health issues	Still unknown effects on workers' health		Potential sickness, dizziness, nausea or eye-strain	
		Psychosocial and physical risks derived of human interaction with robots		
Safety issues	Accidents potentially more frequent during the transition time	- Robots working in unstructured, public environments with human proximity - Uncertainty on liability issues as a result of errors made by robots			
Ethics issues	Algorithm-based decision-making (the Trolley paradox)	'Uncanny valley' effect raising feelings of eeriness and revulsion	Algorithm-based decision-making		Ethical criteria still to be tested
Privacy rights	Invasion of users' privacy and access of personal data			
Cybersecurity	Vulnerability to cyberattacks			

Source: Own elaboration based on Eurofound (2019a), Eurofound (2019b), Eurofound (2019c), Eurofound (2019d), Eurofound (2019e)

6. Interoperability and connectivity: preconditions for increased adoption

In addition to the technical maturity in each specific technology, the interoperability between systems and architectures of existing technologies represents an important precondition for a breakthrough in their adoption and simultaneously, one of the main challenges ahead. Digital transformation is increasingly based on the connectivity and interoperability between technological infrastructures with different functionalities. Most of the technologies analysed in this working paper may support each other, complementing or providing infrastructure in order to achieve fully operational aims and, beyond that, adding exponential capacities. This combination adds value, ability and economic and social sense to the application of each specific technology. In that sense, notably AI and IoT along with big data analytics enable further capacities of each individual technology and allow the creation of technological ecosystem favouring the adoption.

An example of interoperability is the combination of several disrupting technologies to enable road transport devices (cars, trucks) to act autonomously. These vehicles need to constantly adapt to dynamic traffic environments, collecting data through multiple IoT-enabled sensors. IoT-enabled interfaces are crucial to facilitate the interaction of the vehicles with other devices when the autonomous vehicle is self-driving. Analysing and updating the collected data in real-time (traffic data, but also any road data and navigational pathways, including the presence of other vehicles and humans) is critical to the continued driving and is provided by both on-board analytics functions and embedded software platforms. Autonomous transport devices require AI and machine learning techniques to understand the sensor data captured. In turn, robotics platforms also contribute by performing data-specific functions (for example, GPS tracking, odometry) and support the autonomous transport device to drive correctly in dynamic traffic flows. In short, the integration and adoption of multiple and complex disruptive technologies is essential to enable the existence and functionality of autonomous transport devices.

Similarly to autonomous transport devices, AI and advanced data analytic capabilities combine to enable **robot** units to make autonomous decisions and adapt their behaviour to the context they are in. This requires robots with sensors with data collection capabilities and availability of large datasets for training AI applying decision-making by algorithms. In some business activities in the services sector, customer service robots may need to run advanced natural language processing (NLP) software, meaning they can respond intelligently to customer queries while also being able to travel around a public space; this is also the case of autonomous logistic robots, which are able to adapt behaviour in response to incoming requests in order to optimise performance and workflows.

Another example is the integration of **VR/AR** technologies with wearable devices, smartphones, IoT-enabled devices and big data analytics. Smartphones can be deemed as wearable devices as far as they undertake wireless connectivity and offer an easy access to immersive environments using VR headsets (Samsung Gear VR, HTC Vive, Oculus). A key component is wireless connectivity usually in the form of WiFi, Bluetooth, and 4G LTE – and 5G in the future along with other systems - particularly for gaming and entertainment sectors to provide an interactive online and streaming experience. IoT combined with VR/AR technologies would provide data for analytics functions in service activities as marketing, education and healthcare.

Wearable devices technology matches perfectly with IoT capacities. Here, securing connectivity among different devices in households, companies and the public sphere is the key issue. In that sense, some authors have considered the development and adoption of wearable technologies in the context of a wider connectivity trend ('seamless web') led by IoT and involving cloud and smartphones. As in the case of VR/AR, secure and capable connectivity through wireless access or cellular connectivity (for example, 4G and soon 5G) becomes a crucial element for the adoption of these technologies.

Finally, **blockchain** has the potential to be used in conjunction with several emerging technologies which require and are built on top of extensive data interaction such as the Internet of Things, big data, and other more artefact-based technologies such as autonomous vehicles, wearable devices, and virtual/augmented reality. In principle, blockchain capacity to enable storage, access, and transfer of

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data in digital format using cryptographic and security features should be considered as a relevant asset for strengthening the security of IoT platforms and cloud infrastructures. Beyond that, it has been suggested that blockchain-based solutions interacting with wearable devices may enable data storage and management of electronic health records in the healthcare sector. Other blockchain-based solutions are expected to be applied in the future in the context of the adoption of autonomous transport devices (refuelling, energy recharges and payment transactions). To ensure interoperability of blockchain applications, the European Commission is actively participating in the ISO standardisation process for DLT (ISO TC 307).

6.1. Data connectivity is essential for adoption of game-changing technologies

In addition to the combination and interoperability of the technologies, the emerging issue in this complex architecture comes from the essential role played by the real-time data transmission and seamless communication needed. Game-changing technologies need to capture and process data to unleash their full transforming potential. Autonomous vehicles to a greater extent, but also advanced robotics or wearable devices, depend on data availability and accuracy. Data have become a social and economic critical resource (OECD, 2019) and the speed and accuracy at which data are available is crucial to deploy B2B applications or providing services to consumers (and citizens). The dynamic of the data economy implies that the volume of data increases with its collection and use, laying the foundations for the development of new products and services.

In this dynamic environment driven by sensors and devices exponentially transmitting huge volumes of data every day, connectivity emerges as the new key paradigm. Well-secured functionality of near-distance and long-distance wireless ubiquitous connectivity is needed. Adoption of 5G networks is essential to guarantee adoption of emerging applications and services along with the IoT and Edge Computing. These technologies become relevant players to set a disrupting scenario in a wide range of activities in the services sectors and even beyond, in the whole economy and society: where there were 8.4 billion connected devices, objects and things in use in 2017, up 31% from 2016[10], it is estimated that the networked machines could be up to 20 billion by 2020. 5G will provide ultra-high bandwidth and low latency connectivity, that is, the round-trip time between a request and its response in a network. It will enable the work between connected devices and facilitate real-time data collection and analysis, boosting the use of AI and adding value to cloud distribution and storage. In doing so, the 5G infrastructure will contribute to enable the development of new applications and services across sectors, as well as to improve the speed and quality of the existing ones.

The combination of high speed, responsiveness and ubiquity will unleash full capabilities to autonomous vehicles as self-driving cars or drones and AR/VR. For example, 5G could enhance the experience using VR to connect in real time with live-streaming virtual worlds. It seems to be an unstoppable tendency, as customers demand better quality performance of the VR contents. Advanced robotics and wearables will increase the services quality connected to IoT through 5G. Other services which require high-performance real-time response will benefit from the technological progress enabled by 5G, for example, remote surgery. To ensure early adoption of 5G infrastructure in Europe, the Commission adopted in 2016 a 5G Action Plan for Europe, with the objective to start launching 5G services in all EU Member States by the end of 2020 at the latest[11].

In this connectivity scenario, Edge Computing (Multi-Access Edge Computing – MEC) is a telecommunications architecture that goes beyond the possibilities offered by a central cloud or traditional servers by allowing the connection of a plurality of data centres. It makes possible to uphold additional capabilities using the network segments closest to the devices that generate the data. In doing so, many services and applications based on virtual and augmented reality, robotics will benefit from the real-time bandwidth and low latency needed.

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[10] https://www.gartner.com/en/newsroom/press-releases/2017-02-07-gartner-says-8-billion-connected-things-will-be-in-use-in-2017-up-31-percent-from-2016

[11] European Commission, Digital policy: https://ec.europa.eu/digital-single-market/en/5g-europe-action-plan

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Similarly to the race to the moon in the 1960s, the race to deploy broadband networks using very-low-Earth orbit satellites has started. Plans to build a global, high-speed wireless internet network, approved by the US Federal Communications Commission (FCC), have been announced by OneWeb, SpaceX, Telesat, Boeing and Amazon and the launching of thousands of satellites[12]. The possibility to engage billions of new consumers not connected or not consistently connected to the internet are behind this initiative, but also the capacity to optimise cloud services and the use of IoT.

6.2. Increasing risks and vulnerability of data used in services

Apart from the concerns on privacy rights about personal data, the unprecedent flow of connected technologies based on the transmission and storing of data has also security implications. The storage and processing of data can be vulnerable to cyberattacks. Large-scale cyberattacks to companies and institutions could lead to lost, distorted or compromised personal data for large groups of employees or consumers. For example, actors with malicious intent may find weaknesses in the security of communication technologies that aid the transfer of data between wearable devices and smartphones. VR/AR software platforms can also be vulnerable to cyberattacks through vulnerable cloud environments. Most of these software architectures including the use of AI and big data analytics often rely on cloud computing, which could become a target for cyberattacks. Even the distributed nature of blockchain with the decentralised administration of its data nodes makes the technology resilient to complete data loss, it remains susceptible to security and privacy failures as it happened with Ethereum[13]. The complex data transmission and processing ecosystem necessary for the adoption of autonomous transport devices is also susceptible to cybersecurity failures. In that sense, there is still room for legislative and practice improvement at national level in privacy and security protection as well as in liability requirements.

Box 2. Ethics, privacy, security

The pervasive collection of data is a hot topic in the current technological debate. Questions are raised not only in relation to privacy - who owns the data, who uses them, who gains from them, but also about ethical choices being made consciously or unconsciously, for example, when creating an algorithm. The 'moral machine' experiment run by MIT where people where asked how an **autonomous car** should behave when human life is at stake is a well-known case. The issues of trust, safety, privacy and surveillance or cultural acceptance are all areas where technologies could have an impact and therefore merit discussion from an ethical point of view, that is moral principles governing behaviour. These issues touch upon all aspects of life including work and employment.

Legal protection of personal data has improved considerably since the introduction of the EU's General Data Protection Regulation (GDPR) in 2018. Workers' rights to privacy when using employers' digital tools have been established in some Member States, but it is mostly personal data accrued automatically every day, as a by-product of employees' every-day use of digital equipment and applications provided by the employer. Despite the GDPR provisions and specific safeguards to protect sensitive information (for example, about workers' health), personal data flow enabled by the interoperability and hyper connectivity between different technologies remain

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[12] The Verge: *FCC approves SpaceX's plan to launch more than 7,000 internet-beaming satellites* https://www.theverge.com/2018/11/15/18096943/spacex-fcc-starlink-satellites-approval-constellation-internet-from-space

[13] Ethereum is a digital currency released in 2013 (Bitcoin was in 2009) and has grown to be the second largest digital currency in the world by market cap. In 2017, an unknown attacker exploited a vulnerability in the Ethereum network stealing over $31million (near €28 million) worth of Ether tokens in minutes. Equally at the beginning of 2019, another cyber-attack to Ethereum Classic - a spinoff from the original Ethereum – disrupted this virtual currency.

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unsolved on the ground.

For example, the pairing of **robots** with sensors collecting data used in AI application may face legal issues regarding data protection, such as the collection and use of data by robots operating in the workplace concerning their human colleagues or interacting with clients and customers. In addition, ethical issues relating to decision-making by algorithms may also be applicable to robot applications which use advanced AI or machine learning software. This can be applied to the ethical issues raised by autonomous transport devices faced to extreme choices. In this case, the automation nature of driving these vehicles is based on sensors to collect and transmit data wirelessly processed by software platforms.

Most of the **VR/AR** applications pose digital risks in terms of the collection of personal data. These technologies can collect information about the user through different devices (camera, microphone, headset, and so on). Even where anonymised data are collected, the underlying algorithms have the capability to potentially and accurately identify the user by cross-referencing data sources with individuals' 'digital traces'. Similarly, the potential privacy and security implications of data collection and storage provided by wearable technologies represents a serious challenge. Personal data as, for instance, the wearer's location, age, sex, height, weight, preferences or behaviour are highly sensitive.

Finally, it has been suggested that the distributed nature of **blockchain** technology combined with its capability to store data cryptographically would make it more difficult to hack personal data, thus reinforcing the security and resilience of the system. However, some authors have pointed out that although the users' identities are pseudonymised, the details of the transactions are transparent and thus it is not totally clear to what extent blockchain can ensure privacy (as opposed to anonymity) to its users. Perhaps the most important guideline is the one on human agency and oversight which should guarantee that decisions which may not take into account the whole context are not entirely left to the internal logic of an algorithm. In the workplace, this means that human supervision is granted for tasks which can have consequences on workers' safety and well-being, implying that all the levels where human-machine interaction is required have appropriate measures in place, including managerial decisions on the organisation of work. The guidelines are not yet implemented into law, but they indicate a path which should help protect citizens and workers. In terms of AI guidelines' applicability to the world of work a few rules can be derived: companies need to have measures in place to protect workers' and service users' data including clear policies about who owns them, who accesses them and what types of data are used by the algorithms when taking decisions; if the data are biased, the algorithm's rules could reflect the bias and thus discriminate workers.

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7. Impact on the economic process

The economic process of services has some peculiarities that make it more difficult to assess the potential implications of technical innovations compared to those taking place in the manufacturing sector. Whereas manufacturing is at the core a material process of transforming inputs into tangible outputs which have economic value, services include many different types of social relations between a provider and a consumer or user that result in some kind of intangible outcome for the latter. In services, production and consumption are in principle simultaneous and inseparable; the input is supplied by the service provider and the consumer jointly in an open process (compared to the closed process of manufacturing production); and rather than a tangible output, there is an intangible outcome that involves a transformation of the consumer herself or some of her attributes.

This does not mean that technological progress does not have an impact on services. As in manufacturing, technology can improve the outcome (or quality) of the service for a given set of inputs, and in that sense, it can improve productivity. However, the fact that the output is not tangible and often not even measurable (which is why the term *outcome* instead of output is used), makes it very difficult to quantify this effect. According to many scholars, this measurement problem has often been wrongly equated to a lack of productivity growth in services, and more sophisticated approaches (such as the use of subjective measures of quality for services) are trying to solve this problem, with uneven success.

However, the impact of technology in services has probably been much more important in terms of *transforming* the nature of its economic process rather than in improving its output in quantitative or even qualitative terms. In particular, the digital revolution is having a very significant impact on the services sector, transforming its nature in fundamental ways, for instance:

Potential increase in productivity: Even before the arrival of digital technologies, the possibility of recording, storing and reproducing human communication at relatively low cost facilitated the non-simultaneous provision of some types of services, for instance some types of entertainment. If this is seen from the lens of productivity analysis in a traditional way, it can be understood as a massive expansion of productivity: a recorded concert, for instance, can be reproduced unlimited times with minimal costs, and thus the input to output ratio would grow massively or even tend to infinite (however, production-consumption simultaneousness still adds value, and thus there is still a significant demand for live concerts). The use of digital technologies can increase the quality of recorded communication, for instance adding interactivity, which can radically change the economic process of some types of services such as education and training.

Distanceless and borderless services: The improvement of communication possibilities brought about by digital technologies facilitates the remote provision of many types of services, thus making the production-consumption simultaneousness a less radical constraint in terms of space. When the physical presence of the service provider is not crucial, the use of ICT and other technologies allows the service to be provided from anywhere, as already happens for instance in phone-assisted customer services. New advances in digital technologies can expand the range of services that may be remotely provided, for instance by using remotely controlled robots.

Expanded activities and tasks: As previously mentioned, consumers or users typically provide part of the (labour) input in services, and the use of technologies can expand quite significantly the possibilities in this respect. As in the case of recorded communication, the model of 'self-service' provision predates the digital revolution (for instance, supermarkets organised retail service provision in such a way that the consumer could perform many tasks that were previously provided by retail workers), but technology expands quite significantly the range of activities and tasks that can be provided by customers themselves (because they can simplify radically the process), thus reducing the amount of labour input necessary from an organisational point of view.

New business models and business activities: The input provided by customers and consumers inherent to the production process in the services sector opens new possibilities for business models. Software robotics (bots), IoT and other disruptive technologies adopted in service activities have unlocked new business opportunities based on valuing the data collected from users and customers. The use of digital tools for collecting and analysing information on the service provision process can generate secondary sources of profit such as advertising or the selling of data to third parties.

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Cooperation networking in the provision of services: Disruptive technologies adopted in services also uncover new cooperation dimensions based on networking. Using IoT and VR, businesses and institutions are better enabled to collaborate using data-driven and complementary technology. Again, new business models and activities are set up based mainly on sharing potential customers' data, distributive roles and the capacity of entering in new markets bringing returns due to network and alliances between services providers. Scale is also important here as the number of network members affects the ability to reach customers and citizens.

Impact of ethics, behaviour and responsibility in the economic process: Platform-enabled provision of services, along with AI, may expand local operations to the national or global scale and have certainly impacted our way of life. For example, customer services, marketing and sales will be – and some of them already are – data-driven and consequently, analysing and circulating the data will be essential for any business or institution. This interconnected hyper-activity raises social – for example, inequality in the access to services depending on the place one lives and the quality of the internet connection - and ethical issues mainly based on the protection to intimacy, the ownership of data and the potential algorithmic biases. In dealing with these challenges, businesses' and institutions' *digital* behaviour becomes crucial in markets and society as well, expanding the scope of economic responsibility and social accountability. Customers and citizens behaviour are also concerned in this complex landscape.

The five game-changing technologies for European services studied in this report are part of the adoption phase of the digital revolution[14] (Eurofound, 2018), and thus their effects in the services economic process go along the lines previously described. For example, **virtual reality and augmented reality** involve a near complete digitisation of service provision, in which an artificial digital environment is created where social interaction between avatars can take place (in the case of virtual reality) or where digital information or models are superimposed to perceived reality (in the case of augmented reality). The potential implications for the service process are sweeping. Since social interaction in virtual reality takes place between digital avatars, these technologies can facilitate the automation of digital service provision, since the distance between a digitally and a human controlled avatar in virtual reality is much smaller than between a physical robot and a human being in the real world. In addition, these technologies facilitate a (near) total control of the context where the service provision takes place. In virtual reality or augmented reality, the context can become part of the service, and it can collect very detailed information on the process.

Wearable devices are also a form of digitisation of services, although what is digitised is arguably the consumer herself. Using connected miniaturised computers and sensor devices attached to the consumer, detailed real-time data on the consumer and her environment is continuously collected and transmitted for centralised analysis. Wearable devices can be extremely efficient information delivery systems, in both directions, and therefore can significantly increase the efficiency of service provision. Since many services aim at some kind of qualitative outcome in the customer herself, wearable devices can be used to evaluate (and improve) this outcome in real-time to the extent that it has some physical manifestation (for instance, a change in heart rate as a result of a pleasant service). But as previously mentioned, they also involve a big push towards the increasing centrality of data in the service economic process. It is important to note that this matters not only for the efficiency of service provision: the data collected have value in themselves, and are increasingly used as a secondary source of profit, either for advertising purposes (by the service company or third parties) or for the knowledge it embodies (for instance, to be fed to a machine learning algorithm to improve its predictive capacity). So far, the main applications of wearable devices have been in health and sports-related activities, but also in gaming.

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[14] According to a long cycle theory of technological revolution (Freeman and Louçã, 2001; Pérez, 2003), there is an initial period (the 'installation') marked by growing imbalances between the old and new industries. Over the second period of the technological revolution (the 'deployment period'), the possibilities afforded by the technological revolution are slowly depleted. This theory is applied for example to the disruption caused by the Fordism of automobiles, oil and mass production.

8. Impact on labour market

8.1. Implications for employment

In terms of job creation and destruction the five technologies have different impacts across different service activities. First of all, given that most of the technologies are in the early stages of adoption and even in technical development, the long-term implications for employment are only likely to be better understood subject to wider use in specific services activities.

In general, where these technologies imply a service to a person, potential for displacement or substitution arises when the use of the technology makes the customer or user self-sufficient; for instance, the substitution of cashers in supermarkets by customer operated scanning machines has led to a setting where one or two operators are sufficient to supervise a number of machines.

The dual aspect of technology as human-enhancing or human-replacing does not have a definitive answer since many factors are at play. However, looking at the vectors of digital change, it is possible to indicate some automation technologies (advanced robotics and autonomous vehicles) as potentially human-replacing and some digitisation technologies (wearable devices and VR/AR) as human enhancing.

The automation of processes changes the very nature of tasks performed by human workers. Both **advanced robotics** and **autonomous vehicles** could bring job displacements but in different sectors and with different magnitudes. Instead of total replacement of human work, automation can take place in a more nuanced way; it could disrupt work processes but at the same time create new spaces for human-machine collaboration on specific tasks. There is an ongoing and global debate about the extent to which adoption of robotics and AI may replace certain jobs, entirely or partially. Using different methodological analysis, some forecast studies provide figures on what jobs are considered highly automatable (such as those which comprise repetitive, structured tasks, for example, telephone operators) and those considered less automatable (those which rely on high dexterity, creativity, social skills and the ability to respond effectively to changing conditions and unpredictable scenarios). These scenarios and predictions do not prevent that employment and jobs in occupations could be augmented in other ways by the use of advanced robotics. Actually, available evidence suggests that although some jobs involving repetitive or routine tasks may be lost, new jobs requiring different skills to cope with more advanced tasks could be required.

It has been acknowledged (Eurofound, 2016) that because a job consists of many different tasks, not all the tasks in a job could be fully automatable. On the contrary, some tasks would be difficult to automate fully, and advanced robotics might be able to replace some of the tasks, but not necessarily eliminate the job (Eurofound (2019e). For example, as discussed below, professional drivers in road transport undertake tasks beyond driving, such as checking load and unload operations, administrative management at borders, and so on, and these tasks are likely to remain necessary in the future and require human agency. Having been retrained, the workers could potentially be engaged in tasks that go beyond pre-defined routines and may require the workers to regularly improvise at work by using such skills. However, the evidence for the extent to which full-time professional drivers can transition to other jobs and whether they can be retrained for jobs that require creative skills and social intelligence is not conclusive (Eurofound, 2019a).

Additionally, the impact on employment in services as a result of robotisation must also be considered in the context of global supply chains and international trade. For some service jobs which are considered highly automatable (such as telemarketers), it may remain cheaper for the foreseeable future to 'offshore' these roles to human staff in economies in which the operational costs are lower (Eurofound, 2019e).

Within the automation framework, autonomous transport technology is still very nascent and it is difficult to predict the potential impacts on employment and jobs with any certainty or possible timelines for the outcomes. While there are some examples demonstrating real use of autonomous transport devices in Europe, these examples do not yet indicate widespread or highly developed use of the technology. In spite of these time constrains, debates are taking place about the potential impact of this technology on job losses among professional drivers of taxis, buses and trucks. However,

available evidence suggests, as yet, that although some jobs may be lost, the full adoption of this technology may result in the creation of new jobs.

With regard to digitised technologies, expert opinion differs on the extent to which **VR/AR** could see widespread adoption and whether it could displace existing jobs given investment costs related to the hardware and the connectivity requirements. In sectors such as retail, marketing, advertising, or tourism, where existing jobs rely on personalised services, the need for human operators may decrease in the medium term. For example, in the tourism sector, AR devices could potentially replace tourist guides as AR-powered mobile devices grow in popularity, along with the demand for more personalised services across the service sector (Jung and Han, 2014). In retail, the tendency suggests the development of VR/AR-based applications which could reduce reliance on service personnel and change the operational sale system from dedicated (human) salesperson to self-sufficient customers. However, the cost effectiveness of displacing human operators is not yet fully achieved (Eurofound, 2019c).

As **wearable devices** do not necessarily automate pre-existing processes, the risk of workers losing their jobs appears to be relatively low. Instead, the majority of wearable devices on the market are designed to complement human abilities and make employees' work easier, safer or more efficient. Efficiency gains and cost reductions may, in turn, lead to changes in task and resource distribution. Although new job roles, for example, experts of wearables' monitoring systems or data analysis, will be required to support employers in making sense of the large quantities of data collected, overall, there are few signs that wearable devices could have a considerable impact on job creation or loss (Eurofound, 2019d).

Blockchain is still at a relatively nascent stage of adoption and there is, as yet, limited evidence in the literature on the implication of blockchain on job gains or losses. Blockchain as a technology may be able to replace or significantly alter the functioning of intermediary organisations, such as financial clearing houses, including both the low- and high-skilled jobs associated with the operation of such organisations. This may have a broader impact on jobs, and understanding this potential broader impact requires a greater focus on understanding the implications for the institutions – instead of just the specific roles and tasks – vulnerable to disruption. However, a number of new jobs and roles are also likely to be created as a result of wider adoption, both in new industries developing and serving blockchains and within existing organisations and industries themselves seeking to implement the technology.

8.2. Occupational change and skills requirements

The adoption of the five technologies analysed will bring changes in occupations, job competences and skills across services sectors. However, the findings on future skills needed and the changing nature of employment are not sufficiently conclusive in the immediate term, given the early stage of adoption of most of the technologies.

In that sense, **advanced robotics** has four potential areas where it can impact existing jobs: engaging with the robots (medical and care professions), developing the robots (engineers), supervising (testing, monitoring), and new roles not existing yet (Eurofound, 2019e). The ability for robots to automate certain tasks - even if not yet many full services sector jobs - may contribute to the 'parcelling' of tasks, in which skills and tasks become increasingly specialised to augment the work of robot. This may have a broader impact on the nature of traditional occupations, as some tasks in the current portfolio of tasks performed by a certain role (such as a cleaner or receptionist) are automated. Meanwhile, increasing adoption of robot technology may drive demand for jobs that involve engaging with, supervising or developing automating technologies. The human-machine collaboration paradigm in this transition period requests all types of re-skilling and upskilling. Safe, intuitive and user-friendly robot systems implemented in some services based on human-robot interaction need specific technological design and maintenance skills as interface design, communication with machines and ergonomic and safety issues.

As a result, the adoption of advanced robotics in the services sector requires deep changes in skills and education and training policies at all levels. Occupational changes and tasks transformation require sectoral and company approaches to facilitate reskilling, upskilling and training in order for

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workers to collaborate effectively with robots, including retraining in order to account for new robot technologies and replacement models (EU-OSHA, 2015; IFR, 2018).

Autonomous vehicles could mostly impact transport, both of goods and people, and services connected to it such as, for example, the insurance sector. New jobs created may require different - and often more advanced - skills than the jobs lost, such as creative, social intelligence and technical skills. This may pose challenges to the individuals at risk of losing their job without sufficient opportunities or resources for re-skilling to adapt to the changing work environment. The extent to which professional drivers would be able to successfully adapt to the changed paradigm of jobs in the transport and logistics sector remains unknown at this stage of the technology's development Eurofound (2019a).

In the insurance sector, the introduction of autonomous vehicles (self-driving cars) could completely change the type of insurance policies needed, thus requiring a transformation of insurance workers' tasks and of the professional profiles of those who examine accidents who would need to have a deep understanding of algorithms and technologies used.

The adoption of **wearable devices** and **VR/AR** systems does not automate pre-existing processes and consequently, these two technologies impact existing skills differently. Changes will take place mostly in some specific tasks, technical specialists managing and maintaining the equipment, and work organisation. The skills needed in VR/AR in the future depend on the specific implementation in personalised services such as retail, marketing, advertising, or tourism, where a big part of the job consists of some form of social interaction. The use of VR/AR can also lead to increased demand for neuro-cognitive and psychology skill sets in the retail sector (Eurofound, 019c).

It has been noted in relation to wearable devices that new skills are and will be needed involving data processing and data analysis skills, as these devices are generating so much data that it can become time consuming for personnel to review and analyse the data retrieved. The sheer volume of data generated by wearables is likely to require dedicated data managers. Roles such as data scientists and database managers (for example, in the sports sector) able to deal with large quantities of data are likely to be in high demand (Eurofound, 2019d).

Blockchain is unlikely to significanlyt impact on the daily skills applied by individuals in mainstream occupations. Nevertheless, blockchain technology and its applications might alter the content and skills required in some job roles. The tasks and occupations most impacted are services where intermediation is necessary ranging from the legal and notary professions, if smart contracts become mainstream, to education jobs which certify educational and academic credentials if distributed ledger technologies are adopted in the education sector. Some professions would need to develop more technical knowledge, for example lawyers dealing with smart contracts, as well as specialist skills relating to the applications of blockchain technology and general software developer skills would also be required to accompany the implementation of blockchain applications.

Given the lack of widespread understanding about the functioning (and limitations) of blockchain, organisations may also need to provide training for staff, both on the technical aspects of interacting with blockchain applications and on issues relating to interpreting the wider aspects of blockchain, such as the appropriate level of trust in the validity of the data. Some experts suggest that rather than developing a general knowledge of a field, blockchain would drive further specialisation among individuals in the labour market. In line with the wider trend towards digitalisation of services and tasks, skills in science, technology, engineering and mathematics (STEM) are likely to become increasingly important for industries engaging with blockchain (Maupin, 2017).

The above considerations in terms of the impact on employment and skills raise some challenges for both private and public stakeholders. The latter should address the constrains and gaps limiting the adoption of the technologies analysed. European and national legislation in different fields (labour, health and safety, education, technical standardisation, etc.) and action needs to be taken to facilitate the deployment of disrupting technologies.

There is still much work to do related to work systems and management practices to integrate technologies in the workplace. The way work is organised largely influences the extent to which specific tasks can be automated. If work is organised in a way to reduce the importance of key human labour attributes by centralising, standardising and decomposing tasks, the possibilities of automation

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may significantly increase (Eurofound, forthcoming). In this sense, for example, the OECD also notes that, ultimately, the extent to which a particular job is susceptible to automation may also depend on the management style and organisational structures in different countries (Arntz et al, 2016). Therefore, the importance of work organisation as mediating factor in the process of automation of tasks within jobs should not be underestimated.

8.3. Impact on work organisation and work processes

Inherent to the adoption of automation and digitisation in ~~of~~ processes, changes to work organisation in the services sector will be needed. In services, automation does not only consist of the replacement of human activity by automated processes, but it goes beyond and refers to new interaction between the service as such and the user of the service. New interaction methods and flows of information and input deriving by a robot-and-human process should be integrated in the work organisation and in the service production as such in order to maximise productivity and process efficiency.

Continuous task monitoring facilitated by **wearable devices** may provide managers with large volumes of valuable data on employees and consumers and users, which managers can use to make amendments in work organisation and work processes, assignments and routines. Wearable devices in combination with IoT and digitisation systems, as virtual reality or immersive and interactive software combined with sensors, can contribute to profound changes in services, transforming them into data-driven environments. The applicability of wearable technologies stresses the use of real-time progress tracking data to provide accurate information for decision-making in different services activities (design, healthcare services, retail, advertising and marketing services). This flow of information in real-time contributes to more efficient use of resources, which also improves the management of productivity and safety. In retail, wearable devices attached to consumers to track their preferences pre-store and in-store could modify relationships and even the shopping paradigm between sales and customer.

VR/AR technologies offer opportunities to simplify repetitive tasks by offloading some of the worker's tasks and specific steps required in these tasks to machines. In retail, some VR/AR solutions supporting the visual display of products in a store's inventory may reduce time-consuming tasks, such as organising shelves. It has been suggested that VR/AR technologies could support team-working processes by enhancing communication and ensuring that team members have shared situational awareness. This side-effect has relevant application in the military or police sectors, where operational teams rely on quick exchanges of context-related information; the main mode of communication is oral, but under time pressure oral communication risks being understood or interpreted differently among team members.

Given the decentralised and machine-to-machine nature of **blockchain** technology, its impact on work organisation and work processes is, as yet, unclear. On the one hand, blockchain may automate or significantly alter the operation of backroom processes in organisations through applications such as smart contracts and the automation of trust and verification mechanisms performed by third-party organisations. Similarly, blockchain solutions may enable new means of data management within a business, in addition to between organisations. The use of blockchain-based ledgers to store company records and key data may also increase organisational resilience, by avoiding a central point of failure or vulnerability.

8.4. Impact on working conditions

Existing available evidence suggests that some aspects of working conditions in the services sector could be improved with the implementation of some game-changing technologies and notably robotics. There is a clear benefit to the adoption of these technologies with regard to workers' safety. Other aspects of working conditions and job quality are much more difficult to assess at this early stage of adoption and this does not prevent to point out the concerns raised in relation to emerging new forms of health risks and the potential thread for employees' privacy at work.

The extent to which the introduction of **advanced robotics** in a service environment may improve significantly working conditions or create new risks will depend on two conditions. The first condition is the way in which the robot fits into existing work processes, and how it is received by

staff; the second condition is how work organisation is adapted to accommodate the robots. In the services sector where some services are provided with a close contact with other workers and even clients and customers, the design of robotic systems is especially relevant as it should ensure that robot's movements are predictable to human co-workers. Otherwise, workers may be stressed by the perception of a risk.

Robots may replace routine tasks across many services activities as well as work requiring non-balanced work shifts or hard work (heavy lifting) contributing to improve workers' health by reducing occupational risks (musculoskeletal disorders). Furthermore, the key role played by robotics in minimising the risk to humans in hazardous prone professions is well known.

Interestingly, in this human-machine co-existence, it has been widely reported that working alongside robots may give rise to new forms of psychological health impact on workers, including tiredness, stress and depression, for example, caused by the need to 'keep pace' with a robotic system. However, these impacts have not been fully tested and further research is needed monitoring the long-term effects of robot adoption in different sectors.

As discussed above, customers and consumers of the service (such as those requiring health and social care) may also have negative feelings towards the use of robots in particularly 'human' roles. The uncanny valley effect, even though not being a fully empirically tested theory[15], remains a hypothesis given the fast research achievements in human-like realistic androids. Finally, ability of some specific robotics technology as advanced prosthetics, mobility aids and exoskeletons to enable participation of disabled employees or workers with reduced mobility in a greater range of tasks is not always duly acknowledged.

Wearable devices are considered to improve the working conditions of workers in the services sector. This is particularly the case for those wearables that offer direct physical protection (for example, smart gloves), environmental monitoring functionalities to detect hazards, potentially creating a profile of safety risks within a given environment using real time data, and environmental stresses, or communication functionalities to facilitate tactical coordination. Furthermore, wearable devices could be used to gather data on employees to manage workload and to reduce fatigue, work-related stress or ill health. Wearable indicators may also be introduced in the workplace to monitor some physical strains as poor working posture potentially leading to lower back disorders or another work-related harm and painful positions. The same data gathered may encourage employers to reorganise the distribution of working hours or setting health programmes to improve well-being at the workplace. However, employee anxiety has been pointed out as an unintended consequence of the regular use of wearable devices in the workplace, as continuous data collection on employees could generate a feeling of constantly being watched.

Also **VR/AR** technologies may help workers provide more information about their working conditions. VR training environments can contribute to improve worker safety by supporting training workers with specific scenarios in a simulated environment before applying the task in real life (for example, in fire services or in other high-risk jobs). Additionally, some firms report that VR/AR solutions have brought about a reduction in manual, repetitive tasks. Therefore, employees could shift focus to other more appealing tasks of their jobs. Even if mentioned in literature, motion sickness and nausea effects on workers' health due to persistent use of VR devices at the workplace have not been fully proven.

A potential effect of the introduction of VR/AR technologies lies on the decrease of worker autonomy as tasks and work processes become increasingly data-driven and task-driven. As a result, it has been suggested that room for the worker to show creativity and problem-solving in work-related tasks

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[15] According to this theory, stated in 1970 by Masahiro Mori, as robots become more human-like in their appearance, humans tend to show more positive responses towards them. However, once robots reach the stage where they are almost identical to humans, these positive responses dramatically drop into the negatives, with users reporting discomfort, eeriness, and even disgust (Reach Robotics, 12 June, 2018) https://medium.com/@ReachRobotics/traversing-the-uncanny-valley-f630bdf49421

could be diminished. Another potential implication refers to the risk of isolating individual employees in siloed workstations.

It is too early to assess the implications of the adoption of **blockchain** on the working conditions of employees in the services sector. The literature often cites blockchain platforms as an enabler of the further development of the platform economy and other forms of decentralised and freelance work. In this regard, the ultimate impact of blockchain technology on working conditions will depend to a significant degree on the corresponding actions by governments with regard to social security and labour rights in response to such developments.

9. Conclusions

The study examined the potential disruption of five game-changing technologies in the services sector: advanced robotics, autonomous transport devices, virtual and augmented reality, wearable devices and blockchain. The services sector in Europe covers a wide range of heterogenous economic activities with different degree of innovation. Available data confirm that the services sector has been growing fast in terms of employment over the past decades. Among other factors, the servitisation of manufacturing is gradually contributing to increase the whole set of services provided in the economy.

The impact on the economic process in the services sector

Overall, the five technologies analysed in this study share some common attributes which are likely to become increasingly important in the services sector. They all rely fundamentally on digital technologies; they all require and imply the collection of vast amounts of data about the service transactions, the provider and the consumer/user; and with perhaps the exception of blockchain, they can increase significantly the degree of control of the service process by the provider organisation.

By different means, these changes certainly have the potential of increasing significantly the productivity of services: by reducing the amount of labour input necessary for a given service, by increasing the control and potentially the quality of the service outcome, or by reducing the transaction costs. Nevertheless, the main effect of these technologies is likely to be qualitative rather than quantitative: that is, a fundamental transformation of the service process rather than a simple increase of its productivity. In addition, and together with the adoption of ICT, cloud-based services, AI and big data analytics, the use of mobiles and the increasing value of data, business models and work processes are transforming profoundly some specific services activity such as banking or retail.

It is still too early to say how (or even whether) this transformation will be, but some of the key attributes of the five technologies studied may give some hints of its possible direction. The technologies studied imply a significant expansion of the possibilities for remote provision of services, and thus can contribute to an increasing globalisation of the labour involved in service activity (which until now has been mostly confined to national or even very local boundaries). They also imply expanded possibilities for asynchronous, mediated or even automated service provision, which can reduce the amount of labour input necessary in currently existing services (although there may be new services created, adding new jobs, because of the impact of the same or other technologies, so that the final net effect is simply impossible to predict).

Directly and indirectly, the studied technologies increase the centrality of the consumer and users for the service provision: on the one hand, by facilitating further self-service provision and reducing the importance of labour input by the provider; on the other hand, by making information directly obtained on the consumer or user an important source of value in itself. All the technologies studied boost the possibilities for information gathering and data intelligence and contribute to the well-known increasing centrality of data in economic processes, also in services.

Tendencies in applicability and adoption

Automation has the widest and cross-cutting applicability across services. Robotisation is rapidly evolving through different forms and in combination with AI and IoT using big data analytics can result in a widespread implication in specific sector activities. Technological limitations at this stage of adoption refer to the social and communication capabilities to interact with consumers and users. Applications already in place show huge potential for further development in logistics, civil and public services and health care.

The ongoing research on autonomous transport devices and namely self-driving cars shows promising results and raises great expectations, although experts do not agree on the time frame for the adoption of this disruptive societal and economic technology. While the technology is advanced, road-testing is ongoing and traditional and new carmakers are investing in R&D together with big tech companies (Google, Amazon) or other global players (for example Uber, Huawei, and so on), there is still uncertainty on when this technology will be commercially implemented. Technical development does not mean immediate adoption, as other factors (business investment, data infrastructure adequacy, regulatory framework, cultural acceptance, etc.) strongly influence the readiness for application. It suggests that this technology will require gradual and likely uneven degree of adoption across sectors and regions. It is recognised that autonomous vehicles will disrupt not only the transport (including drones but also railway and shipping), but also other economic activities in the services sector.

The impact on employment of these two automation-based technologies is hard to predict. The adoption of technology depends on multi-faceted factors, let aside the time span for the technical development as such (R&D, readiness test, marketisation, and so on) or the acceptance and integration by society. Nevertheless, automation enables business models in service sectors to become less labour-intensive, as the experience in the banking services shows where some tasks have already been automated.

Digitisation-based technologies as wearables devices and VR/AR seem to have a clearer and smooth application in specific services activities, subject to progress in reducing or adjustment of infrastructure costs as well as development in virtual contents and products. VR/AR benefits from its strong cross-cutting applicability across services through its continuous adoption in training simulations, inspection, medical and education services as well as other professional services.

With existing technology, virtual reality is still not sufficiently developed to replace the real world for the provision of most services and remains important only in specialised service industries such as gaming and entertainment. However, as technological progress solves some of the problems of current virtual reality systems (for instance, the discomfort felt when use is prolonged), it can have wide applicability for areas such as education, marketing or healthcare. Most of the applications of these technologies benefit from being product-based (for example, smart gloves or glasses in the case of wearables), that is, can be easily used by individuals through different devices like smartphones, tablets and headsets (VR). All in all, both technologies show promising possibilities for further adoption, ranging from consumer services to B2B applications, although it will be conditioned by the instalment of fast and reliable data transmission and processing infrastructure to facilitate real-time use. The impact of these digitised technologies on employment levels does not seem too high and job loss will be likely compensated by the creation of new jobs with different skills profiles.

The development of blockchain or any other DLT-based technology seems more contentious; there is consensus on the technology being still in its infancy, considering the level of acceptance, adoption and implementation. To overcome these limitations, the European Commission is promoting the adoption of blockchain technologies through a set of ambitious initiatives (Observatory, Funding, Partnership, Forum) aimed at reinforcing cooperation between industry stakeholders and regulators, notably for a regulatory framework as well as supporting international standard setting. In any case, the potential of disruption for blockchain applications is expected to be high both in terms of economic impacts and in terms of employment.

Broader policy implications

Concerns have been reported in different areas related to the adoption of the technologies. Most cited is the potential thread of intrusive practices of employee surveillance compromising privacy at work. Most of the technologies studied enhance the flow of large quantities of personal data embedded into work organisation systems.

The landscape in the services sector is challenged by the increasing role played by enhanced customers who become value co-creators in the service production and delivering process, changing the value configuration of the business as such.

There is a consensus in the literature that, in order to accommodate those who may lose their jobs due to automation (particularly if this corresponds to a whole occupation, such as vehicle drivers), broader policy initiatives relating to skills and education are required. Public policies delivering answers

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boosting technological change and digital transformation must include the mitigation of the negative consequences for individuals and groups at risk of losing their job. The role of public authorities is particularly relevant addressing those without enough opportunities or resources for re-skilling to adapt to the changing work environment.

The uncertain period of digital transition taking place in the services economy – as in manufacturing - poses huge challenges for companies, sectors and society. In this rapidly evolving context, investing and supporting the adoption of game-changing technologies will help to position the EU at the forefront of innovation and uptake.

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