WORKING PAPER

Digital Age

Blockchain: Implications of game-changing technologies in the services sector in Europe

Game-changing technologies: Transforming production and employment in Europe

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This working paper on blockchain is one in a series of five presenting the findings of a study that examined the socioeconomic implications and applicability of game-changing technologies to the services sector in Europe. The other working papers in the series refer to the following technologies: advanced robotics, wearables, autonomous transport devices and virtual reality and augmented reality.

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1. Introduction

Recent technological developments, underpinned by the growth of the internet, have implications – both positive and negative – for a range of sectors and stakeholders. However, while the potential implications are wide-ranging, they are not necessarily predictable, linear or deterministic. Developing a better understanding of the implications of the complex issues associated with technologies is therefore of critical importance for governments, policymakers, businesses, academia and citizens.

Incremental progress in technology could be expected to result in various economic and societal changes. However, technologies termed ‘disruptive’ or ‘game-changing’ are those transformative technological innovations with the potential to significantly reshape the way society does things, whether these be business and organisational practices or more generally associated with everyday life. Some technologies – such as artificial intelligence (AI) or improvements in battery storage – may develop as the result of incremental progress in a field and used in new, game-changing ways. Others – such as autonomous vehicles or blockchain – may provide opportunities for a fundamental reshaping of existing business and market practices and social organisation. While the impacts on markets and national economies are the most prominent examples, the changes go beyond the economic sphere. Significant shifts in business and consumption patterns may have wider socioeconomic implications as a result of the changing economic and labour patterns caused by the technology – such as the loss or displacement of some jobs, the creation of others, or the demand for new skills.

While the role of new technologies in reshaping the manufacturing sector has received noteworthy attention (Eurofound, 2018), there are also key implications for the services sector. As noted in the previous section, as described in the following section, the services sector is taking on an increasingly important role in the EU economy. Understanding the implications of game-changing technologies on the services sector will be essential for realising their benefits to society and the economy in Europe, as well as for minimising and preparing for the likely threats presented by the wider adoption of these technologies. The ‘game-changing’ context here refers to the potential of such technologies to critically influence or significantly change outcomes related to existing markets, market actors, established value chains, prevailing legislative, regulatory paradigms, economic thinking, and socio-political order, amongst others. [1]

This working paper – one in a series of five working papers – presents the findings of a study that examined the socioeconomic implications and applicability of blockchain to the services sector in Europe. This chapter presents the key objectives of the study, articulates the research approach adopted by the study team to meet the study objectives, and outlines the structure of the working paper.

1.1 Objectives of the study

The overarching objective of the study is to assess the potential applicability of the following five emerging and potentially ‘game-changing’ technology areas to the European services sector and the wider socioeconomic implications (Figure 1):

- **advanced robotics**;
- **autonomous transport devices**;
- **blockchain**;

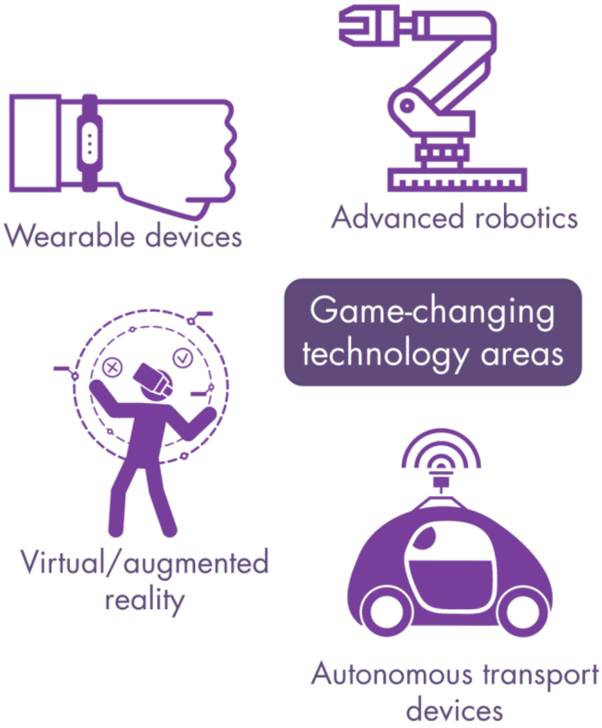
[1] Since there is no canonical definition of ‘game-changing’ technologies, as described here, game-changing technologies correlate to the concept of disruptive innovation which is often used to describe innovation that results in the creation of new markets and in some cases displaces existing market mechanisms including businesses, value networks, products and services. See Bower and Christensen (1995).

- **virtual and augmented reality (VR/AR)**;
- **wearable devices.**

The study has the following four specific objectives:

- **Objective 1:** to assess the scope of applicability of the five technology areas to the services sector (and relevant subindustries where possible) in Europe;
- **Objective 2:** to examine the potential implications of these technology areas on productivity and output and on work organisation;
- **Objective 3:** to analyse the potential implications of the technology areas on employment and on skill levels;
- **Objective 4:** to assess the potential implications on working conditions (including implications for and interaction with individual and collective employment relations systems).

Figure 1: The five 'game-changing' technology areas covered by this study



Source: RAND Europe.

The five technology areas identified in the study are, to varying degrees, still in their infancy, in terms of (potential) widespread commercial applications and wider implications, yet they may have significant implications for the future of the services sector in Europe. The technology areas are listed in Table 1, along with brief high-level descriptions. The descriptions are not intended to be prescriptive or comprehensive; they serve as a general guide to the manner in which each technology area has been interpreted in the context of this study. In chapter 2, the working paper goes into more depth about the descriptions and characteristics of the specific technology area that is the focus of this working paper, namely, blockchain.

Table 1: Brief high-level descriptions of the five technology areas

Technology area	**Brief description**
Advanced robotics	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 (Grant, 2012).
Autonomous transport devices	Autonomous transport devices are a field of technology that will allow vehicles to sense their environment and navigate without human input (Rohr et al, 2016).
Blockchain	Blockchain technology is one of the most well-known uses of distributed ledger[2] technologies (DLT), in which the 'ledger' comprises 'blocks' of transactions, and it is the technology that underlies a cryptocurrency such as Bitcoin (Deshpande et al, 2017).
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	'Wearables' are technology devices comprised of an ensemble of electronics, software and sensors, which are designed to be worn on the body (Billinghurst and Starner, 1999).

Sources: Azuma, 1997; Billinghurst and Starner, 1999; Deshpande et al, 2017; Grant, 2012; Rohr et al, 2012

The five technology areas cover a wide spectrum of potential uses and outcomes associated with the underlying technologies. These vary from more artefact-based use cases related to autonomous transport devices, wearable devices, and virtual/augmented reality, to blockchain, which could be considered an underlying (back-end) technology that provides the basis for the application of the technology in relation to specific uses. Furthermore, there are overlaps and commonalities between the technology areas themselves depending on the manner in which they are interpreted and characterised, for example, advanced robotics and autonomous transport devices (in the context of drones) or virtual/augmented reality and wearable devices (in the context of the way in which 'devices' are interpreted).

Recognising that the technology areas are in different stages of development and adoption, the study team adopted the following timelines (with 2018 as the baseline year) as a reference when discussing the trends and implications of the technologies:

- 'Near or immediate term' refers to the developments likely to take place within the next 1–3 years
- 'Medium term' refers to developments likely to take place within the next 4–7 years
- 'Long term' refers to developments likely to take place in 8 years and beyond

[2] 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.

These timelines were informed by an initial scan of the available evidence and in consultation with expert advisors (see the annexes for more details).

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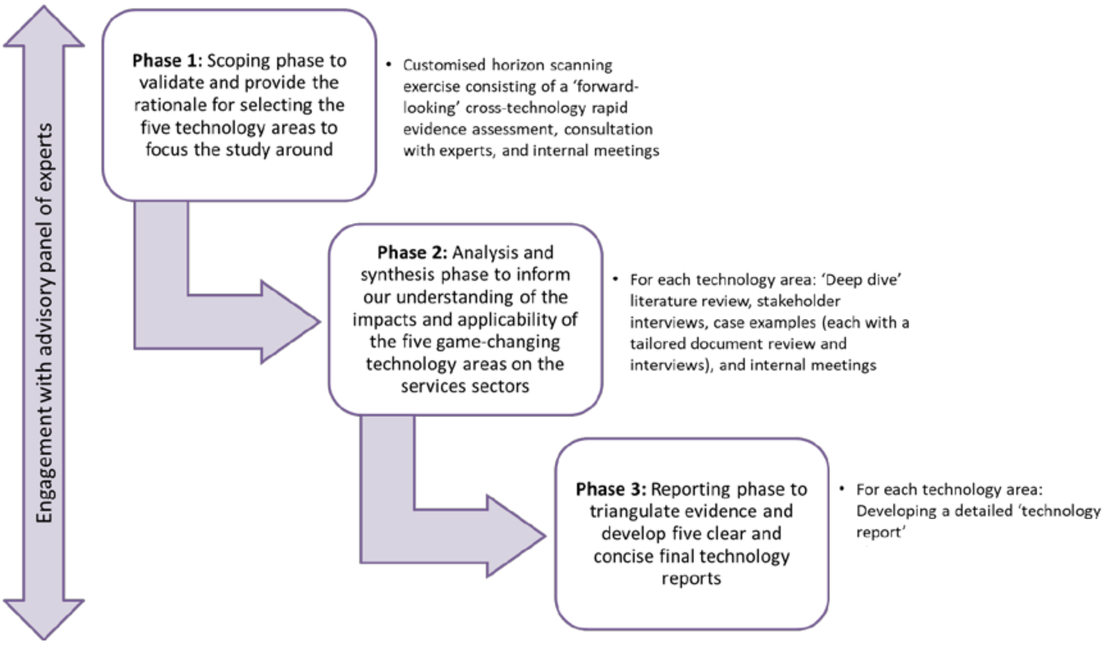
1.2 Research approach

The study was conducted from November 2017 to November 2018, and organised in three discrete but overlapping phases, as illustrated in Figure 2. Each of these phases is discussed in turn in the sections below.

The study team adopted a mixed-methods approach to design the study, relying on a set of carefully selected methodologies within each phase that were tailored to the study requirements. Throughout the study, the study team regularly consulted members of its advisory panel of experts (for example, to identify additional articles to review, to validate search terms, to suggest potential case examples and interviewee names, and to review the study team's analyses). Additional context on these phases is provided in the annex, which also discusses the the limitations of the findings presented in the working paper.

Figure 2: Overview of the main study phases



Source: RAND Europe.

1.2.1 Phase 1: Scoping phase

The aim of this initial phase was to validate and provide the rationale for selecting the five technology areas to focus the study around, namely:

- advanced robotics;
- autonomous transport devices;
- blockchain;
- virtual and augmented reality;
- wearable devices.

Following discussions with Eurofound during the kick-off meeting, this 'validation exercise' was primarily aimed at assessing the extent to which these five technology areas remained relevant to the goals of this study. In addition, the validation exercise was aimed at ensuring that other emerging technology areas and existing technologies with transversal impact on the five technology areas were also considered. To implement the work in this phase of the study, the study team conducted a quick scan of the available evidence in the literature, as well as three scoping consultations with stakeholders that included cross-sector technology and socioeconomic experts.

1.2.2 Phase 2: Analysis and synthesis phase

The study team aimed to collate and assimilate evidence related to the scope and relevance of the application of the technology areas to services sectors in Europe, their wider socioeconomic implications (for example, for employment, skills and working conditions, and work organisation and productivity), and specific case examples to provide illustrative snapshots of their applicability and implications. To this purpose, the study team used a bottom-up, evidence-based approach.

For each of the technology areas, the authors carried out a comprehensive document review, web searches and conducted at least three key informant interviews with different stakeholders.

1.2.3 Phase 3: Reporting phase

Finally, the study team triangulated the findings with respect to each technology area in a way to address the main objectives of the study.

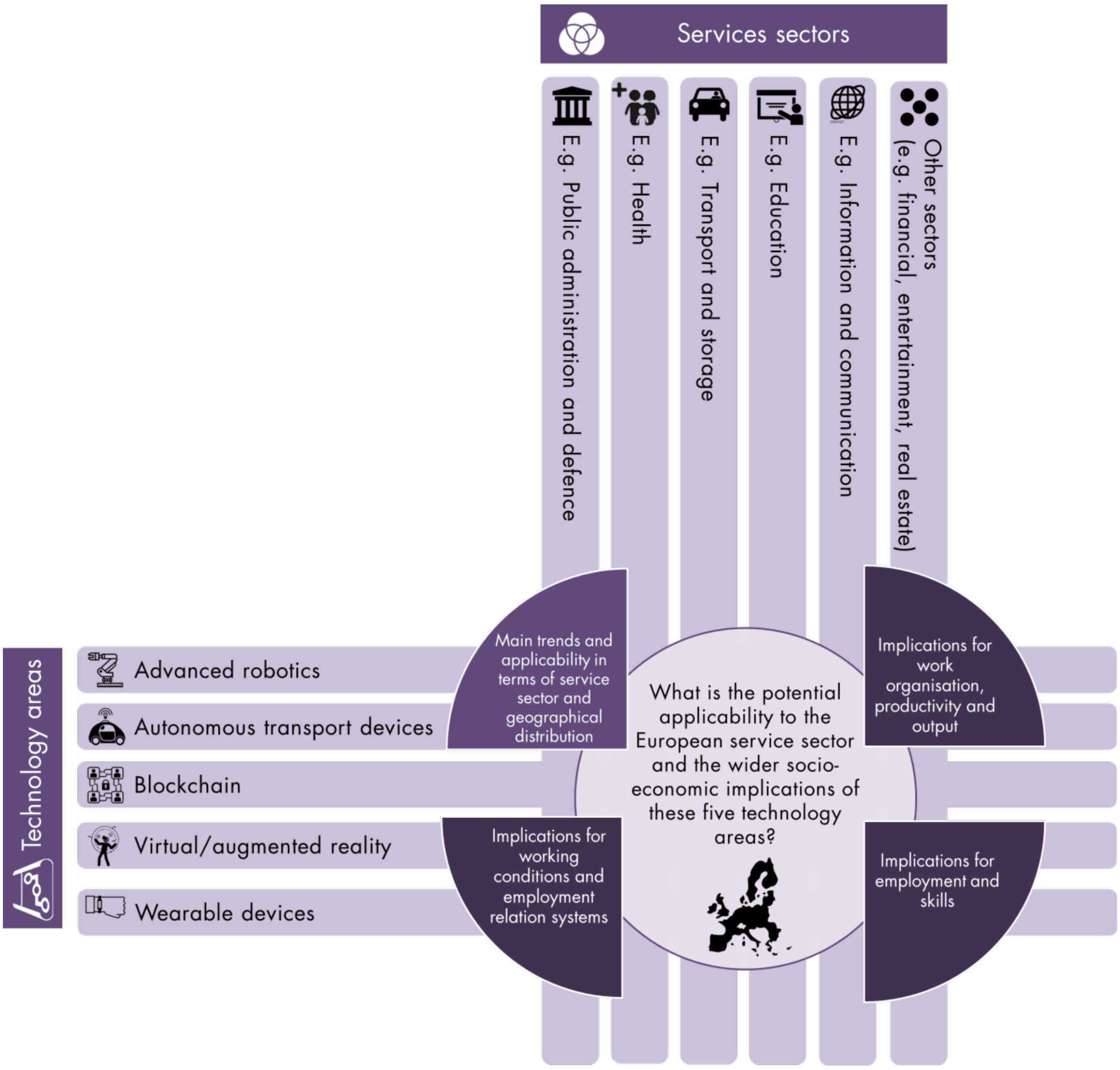
1.2.4 Conceptual framework

The conceptual framework for the study (Figure 3) provided an analytical instrument to assess the applicability and potential socioeconomic implications of the five selected technological areas to European services. First, for each technology area, the study team acquired a general understanding of the important *trends* that are taking place; this enabled the team to portray a picture of the current state of play of each technology, as well as its general direction of travel in the near to medium term. In parallel, the study team also analysed some of the notable driving forces (that is, enablers) for and barriers to the development and adoption of the technology areas.

Second, the study team examined the (potential) *implications* of these technologies on several areas broadly linked to *employment* (for example, the changing nature of employment and tasks) and *working conditions* (for example, contractual arrangements and health and safety), skills (for example, levels and types), *work organisation* (for example, task allocation, work schedules) and *productivity*.

The study team cross-analysed these factors in the context of different services sectors (and subindustries where possible) and geographical areas in Europe. Furthermore, where data are available, relevant snapshots on how the state of play varies in other parts of the world (for example, in the USA, China and Japan) have been provided. The study is largely qualitative in nature, but, where feasible, relevant quantitative data sources have been used to demonstrate the (potential) implications of the five technology areas.

Figure 3: Conceptual framework for the study



Source: RAND Europe

1.3 Structure of the working paper

The rest of this working paper is structured as follows:

- **Chapter 2** provides an in-depth discussion about the development and adoption of blockchain across the services sector. It highlights the main trends that characterise the development of blockchain, as well as the associated driving forces and barriers. Some examples of specific applications in the services sector are also discussed.
- **Chapter 3** presents a detailed analysis of the socioeconomic implications of blockchain on several key areas of the services sector, such as employment, skills and working conditions, and work organisation and productivity.
- **Chapter 4** brings together the key findings of the study against the primary objectives and the main elements of the conceptual framework.
- **Chapter 5** includes three ‘real-world’ case examples that demonstrate the applicability and implications of blockchain in the services sector in Europe.

- The **annex** contains additional details about the research approach, including the search strategy for literature reviews and the interview protocol, and discusses limitations of the analysis presented in this working paper.

2. Development and adoption of blockchain in European services

This section provides an overview of blockchain as a technology area in conjunction with the overall trends shaping the landscape, important drivers and barriers for the adoption of blockchain, and potential applications of the technology.

It should be noted that, given that few blockchain solutions have been implemented for a significant length of time, the body of literature is not advanced and primarily focused on the anticipated, rather than the observed, economic and social outcomes. The study has been prepared with this limitation in mind.

2.1 Overview of blockchain technology

Blockchain technology is one of the most well-known examples of a distributed ledger technology (DLT). A distributed ledger is a digital ledger (a computer file used for recording and tracking transactions) that stores information on a network of machines, with changes to the ledger reflected simultaneously for all holders of the ledger (Deshpande et al, 2018). In the specific case of blockchain, the ledger is cryptographically authenticated by the network, and data are added in batches, thereby comprising a 'chain of blocks' of data, meaning that all 'nodes' - participating devices - share one record of data.[3]

This idea of a 'chain of blocks' was first proposed as the system underlying the Bitcoin cryptocurrency[4] (Nakamoto, 2008), to provide a method of verifying the proper owner of a particular currency token. When a transaction is initiated (in which a Bitcoin holder communicates that they wish to transfer ownership over their unique Bitcoin string to another user), the existing ledger is examined by the network to ensure that the transmitting party is in fact the true 'owner' of that unique Bitcoin, based on the record of past transactions.

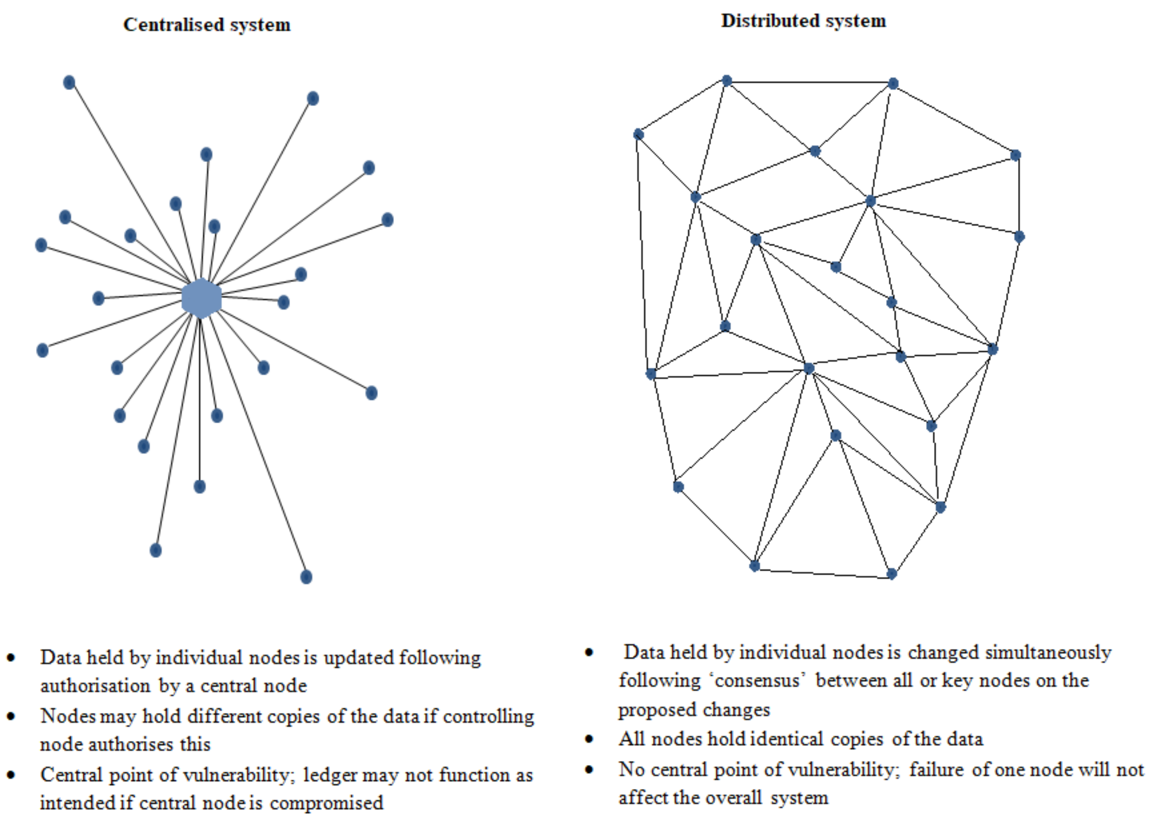
As all nodes must concurrently 'agree' on the content of the ledger, the result is that each block of data is in effect immutable and *uneditable* without the agreement of a majority of the nodes.[5] In doing so, distributed ledger technology solved the 'double-spend problem' of digital currencies: the network is able to confirm the 'true' owner of the digital currency (for example, a Bitcoin or other digital asset expressed as a unique string of code) without the need for a central authority to confirm ownership, as in the case of a bank transaction, or a physical token, as in the case of cash transfers. Figure 4 provides an overview of the main features of centralised and distributed ledgers.

[3] As discussed below, there is some inconsistency in the use of the terminology. Sometimes the term 'blockchain' is used to mean all forms of distributed ledger technology (DLT), and sometimes it is used to mean the specific DLT design in which the shared ledger comprises a 'chain' of information. This working paper follows normative practice by using the term 'blockchain' as shorthand to refer to all forms of DLT with the associated features relating to permanence, immutability and distributed control.

[4] Bitcoin is an open source, decentralised, peer-to-peer payment network maintained by users, with no central authority. Bitcoin provides completely digital money for transactions on the Internet/web (i.e. it has no offline equivalent). For more details see Bitcoin (2019) and Glance (2015).

[5] For further information on the design and functioning of blockchain technology, see Hileman and Rauchs (2017).

Figure 4: Main features of centralised and distributed ledger systems



Source: Adapted from Baran, 1962.

Although early activity focused primarily on Bitcoin and other cryptocurrencies, in recent years blockchain has also received increasing attention for its potential application for other business uses by enabling a secure and trustworthy database which can be shared by multiple parties while being controlled by none (for a detailed discussion of the potential applications of blockchain in the services sector see chapter 2.4, and chapter 5 presents three examples of 'real world' applications of blockchain in the services sector). Figure 5 shows the relative popularity of Google worldwide searches for 'blockchain' between December 2013 and 2018

Figure 5: Frequency of Google searches for ‘blockchain’ worldwide, December 2013 - December 2018

Source: Google Trends data. The peak of 100 indicates the maximum number of weekly searches yet recorded; other weekly search numbers are displayed as a percentage of this maximum figure.

Subsequent blockchain designs have modified the various components of the Bitcoin model, including using alternative ways of reaching ‘consensus’ regarding the content of the ledger, but the fundamental principles remain the same: a shared ‘database’ in which data, once added to the ledger, can only be modified according to protocols set between parties or through a consensus algorithm which garners ‘agreement’ from other devices in the network that the data are being added or amended according to agreed software rules.

In enabling a ledger that is for all intents and purposes an immutable record of information without the need to rely on a central authority, blockchain has the potential to transform the storage, verification, control and sharing of data (including that about ownership of assets, such as cryptocurrencies). In doing so, blockchain technology could enable a number of new, decentralised applications and functions and - according to its supporters - radical new forms of social and economic organisation. Iansiti and Lakhani (2017) draw a parallel to the innovations brought as a result of the development of the internet: just as the internet enabled the peer-to-peer exchange of information (without the need for central intermediaries) and lowered the cost of connections,[6] blockchain enables the disintermediated exchange of value. In this regard, blockchain represents ‘the first native digital medium for value, just as the internet was the first native digital medium for information’ (Tapscott and Tapscott, 2016).

Box 1. The layers of a blockchain

In this working paper, three different layers are used to describe the various elements of the blockchain process:

- **The infrastructure layer:** the chain of blocks itself, including the protocols relating to operation (for example, consensus between nodes);
- **The services layer:** elements of the blockchain which enable the operation of different functions, such as wallets for tokens, data storage and smart contracts;[7]

[6] Thus ushering in the socioeconomic changes that are observed as a result of digitalisation.

[7] A smart contract is a contract programmed into software which automatically self-executes once a set of conditions has been fulfilled. For more information, see discussion in chapter 3.1.3 and Fawcett et al (2018).

- **The application layer:** elements of the blockchain solution relating to the specific application, such as the user interface and application logic.

Developers and organisations may focus on offering services at one of these layers, or build an application from the ground up.

Source: Adapted from Deloitte, 2017.

Blockchains can broadly be grouped into two types (Deshpande et al, 2017):

- ‘permissioned’ (in which the ability to interact with the blockchain is restricted to a set group of nodes);[8]
- ‘permissionless’ (in which the ability to interact with the blockchain is open to any operator, as in the case of Bitcoin).

The choice of permissioned or permissionless ledger for a particular sector will ultimately depend on the extent of control required over the ledger by the intended application (for example, the ability to edit the data). Table 2 provides an overview of the main considerations with regard to the permissioned/permissionless nature of the ledger.

Table 2: Utility of permissionless versus permissioned blockchain for different use cases

Permissionless blockchains may be more useful in cases which involve:	**Permissioned blockchains may be more suitable for cases which involve:**
• Large, multi-participant operations involving unknown parties • Lack of a trusted intermediary or process to verify participants • No need to revise previous transactions • Transparency of the record is acceptable	• Need to edit or remove data recorded on the blockchain (for example, ‘right to be forgotten’) • Desire to restrict writing and access permissions to a known group of operators • Need to ensure anonymity/confidentiality of transactions • Need to enforce protocols for governance, maintenance and updating of the software

Source: Based on Ernst & Young, 2017.

2.2 Trends shaping the blockchain landscape

Box 2. Summary of key trends in the blockchain landscape

- The interest and activity (for example, in terms of patents and publications) in blockchain technologies have seen a sharp rise since 2013.
- Blockchain applications are starting to reach the market, with interest from both start-ups and established companies.

[8] Some papers (for example, Smith et al (2016)) make a distinction between permissioned and private blockchains. Permissioned blockchains are open to all to view but in these blockchains only approved nodes are able to write to the blockchain, while private blockchains are entirely restricted to a single entity or set of known operators. In practice, there is little difference in the operation of the ledger, with the main difference being who is able to view the data. For the sake of simplicity, this working paper uses ‘permissioned’ to refer to both types.

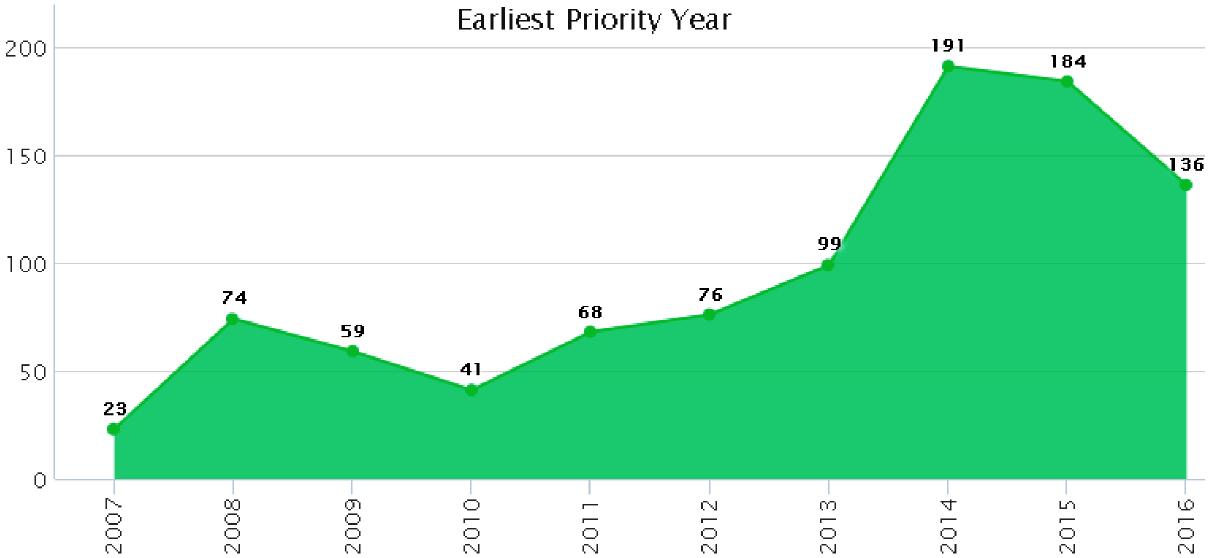
- Development to date has often been the result of open communities, although there is strong interest at national and EU level.

Given that blockchain technology is still developing and yet to see widespread market adoption, following analysis uses patent applications and research publications related to blockchain as signals of market interest and activity in the technology.[9]

2.2.1 Interest and activity in blockchain technologies since 2014

Figure 8 depicts patent activity related to blockchain technologies[10] between 2007 and 2016.[11] A general upward trend is observed in the filing of blockchain-related patents from 2007 to 2014. A slight dip in the numbers is noted in 2015 and 2016. This most likely reflects the changes in patents filed in relation to the specific subset of blockchain technologies considered in the following chart. [12]

Figure 6: Global trends for patents filed for blockchain technologies, 2007-2016



Source: PatSeer Pro, 2017. Reproduced with permission from PatSeer Pro, a Gridlogics Technologies company. The term earliest priority year in the figure is a reference to the earliest year in which the priority application for the patent was filed (PatSeer Pro, 2017). Priority application for a patent is done to make an early claim on the idea and ensure it is registered before a competitor with a similar idea can file a patent.

[9] This discussion draws on the patent landscape reports available via the World Intellectual Property Organization's (WIPO) website and the data on patents and research publications published by the Tools for Innovation Monitoring (TIM) created by the European Commission's Joint Research Centre (JRC). See the annex for further discussion (including possible limitations of this approach).

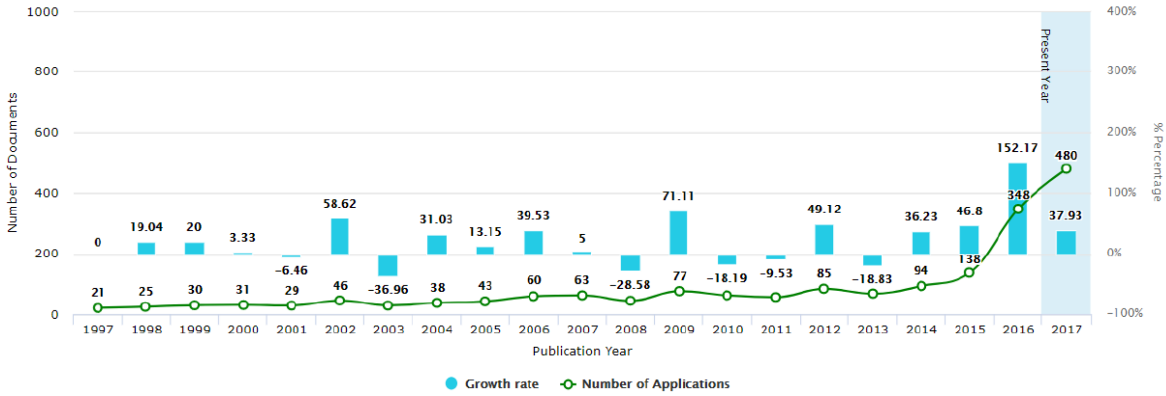
[10] This analysis is based on the PatSeer Pro (2017) report, in which blockchain is identified as a type of distributed ledger, comprised of unchangeable, digitally recorded data in packages called blocks.

[11] The aspects of blockchain technologies covered by these patents include: constructive technologies, common standards, protocols, cryptographic methods, and applications (PatSeer Pro, 2017).

[12] This figure is based on an analysis of patents based on information in the public domain. The patents were grouped together into one member per family. Patent family refers to a group of one or more patent applications in multiple countries which represent the same invention. Thus the chart depicts data for a patent family rather than the absolute number of patents. See PatSeer Pro (2017) for further information on this approach.

A similar trend is seen in Figure 7, which covers an overlapping but different subset of blockchain technologies.[13] Although the growth rates on patent applications vary year-on-year and no discernible trend is seen (the cyan-coloured blocks), an incremental growth can be noted in the number of applications (the green line), with a significant growth in patent-filing activity from 2015 onwards.

Figure 7: Global trends for patents addressing technologies and applications related to blockchain, 1997-2017 [14]



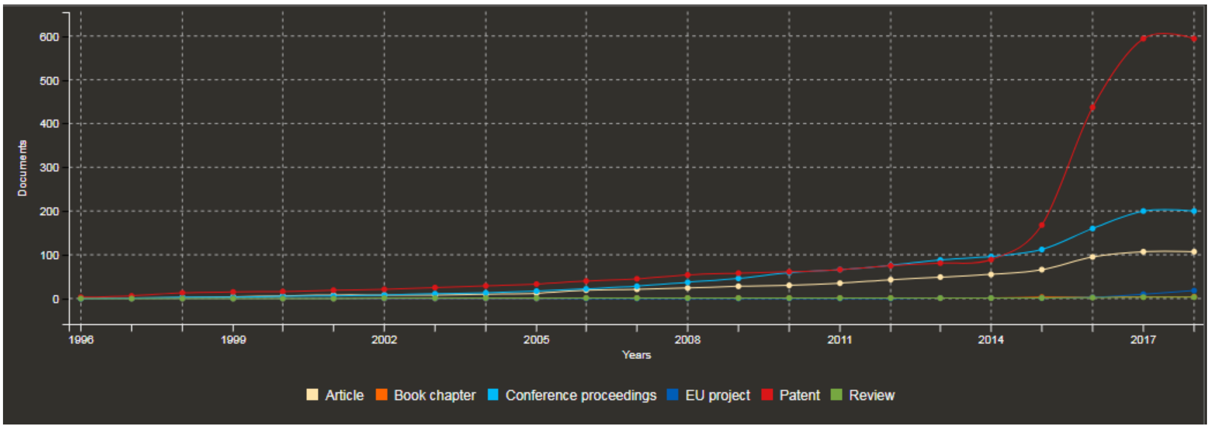
Source: Relecura, 2017. Reproduced with permission from Relecura Inc.

These observations regarding the overall trends related to the activity on technologies and applications related to blockchain are also reflected in the trend across a number of different outputs other than patents. Figure 10 draws on the findings from the Tools for Innovation Monitoring (TIM) project (Tools for Innovation Monitoring, 2018). The underlying data for this analysis are based on EU projects, patents, conference proceedings, book chapters and articles that either contribute to blockchain technology or are focussed on blockchain as a core technology.

[13] This analysis is based on the Relecura (2017) report, in which blockchain is identified as a ledger that stores information of all cryptocurrency transactions that have ever been executed. The transactional details are stored in a continuously growing list of records, called blocks. These blocks are linked to each other and secured using cryptography. The Relecura (2017) report covers the following subsets of blockchain patents: data transmission, digital data processing, data processing systems, cryptography, and wireless communications networks.

[14] Since blockchain is considered a type of distributed ledger, it is built on top of a number of component technologies and applications, including data transmission, data processing, storage protocols, and cryptography. This analysis considers a wide array of technologies and ideas that contributed to blockchain as a technology area; therefore the timeline of the data considered dates back to 1997 despite the relatively nascent nature of blockchain itself as a technology.

Figure 8: Global trends for technologies and applications related to blockchain (including patents and research publications), 1996-2017



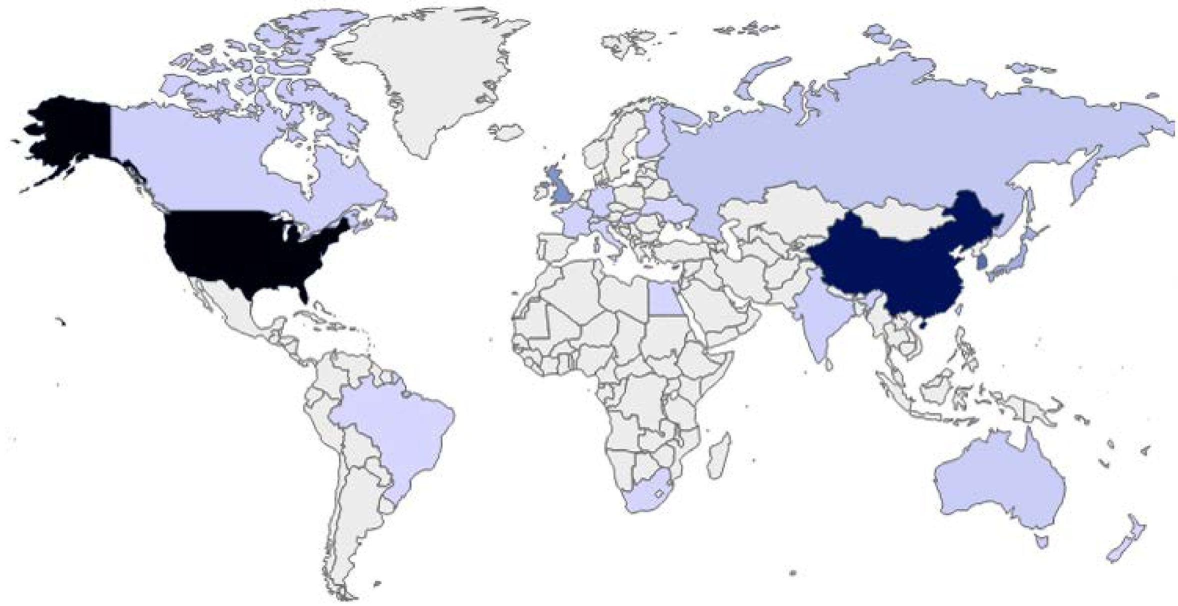
Source: Tools for Innovation Monitoring, 2018. Original sourced with permission from the European Commission JRC, TIM project.

Figure 9 presents the global geographical distribution of blockchain technology-related patents (the data relate to the same subset of patents on blockchain technologies identified in Figure 8). The USA and China appear to have the most substantial patent activity, with the USA ahead of China in terms of the number of patents filed. This is followed by South Korea, the UK and Japan. Within the EU, the UK appears to be the leader in terms of number of patents filed. The USA's dominance is likely to be due to it being the base of IBM, Microsoft and Bank of America, which are among the top patent holders for blockchain technologies worldwide (Relecura, 2017). When the worldwide trends are considered, Nokia (Finland), Alcatel-Lucent (France), British Telecom (UK), Sony, Toshiba, Panasonic, and NEC (all of them Japan), and Bubi (Beijing) Network tech Co Ltd (China) are organisations active in filing blockchain-related patents (Relecura, 2017).

Although EU countries do not appear to be among the top patent holders when considered individually, analysis of the TIM project data suggests that when patent activity across the EU is considered as whole, the EU is second to the USA in terms of the total number of patents and other blockchain-related outputs (including research publications) (Tools for Innovation Monitoring, 2018). The map in Figure 11 depicts this activity based on the 2016 data, with darker shades of blue colour indicating more number of patents filed.[15]

[15] The patents have been grouped together into one member per family. Patent family refers to a group of one or more patent applications in multiple countries which represent the same invention. Thus the geographical distribution depicts data for a patent family rather than the absolute number of patents. See PatSeer Pro (2017) for further information on this approach.

Figure 9: Geographical distribution of blockchain technology-related patents globally, 2016



Source: Based on PatSeer Pro, 2017. Reproduced with permission from PatSeer Pro, a Gridlogics Technologies company. Darker shades of blue colour indicate more number of patents filed.

The above analysis shows that the overall market interest and activity in blockchain as a technology area has been increasing across the world, with the USA, China, Japan, South Korea and the UK being the leaders when the number of patents filed is considered. Within the EU, the UK is a clear forerunner, with Germany, France and Spain being the other countries active in filing patents.

2.2.2 Blockchain-based applications on the market

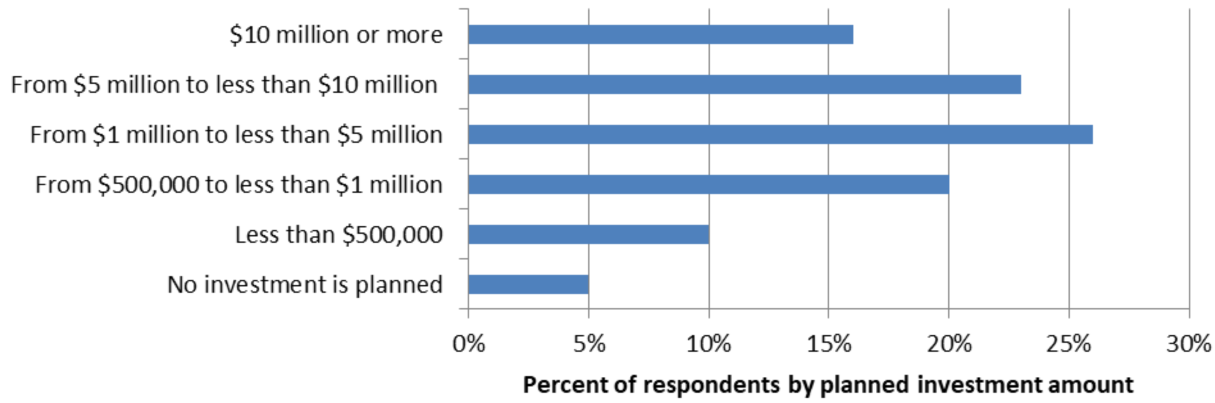
According to an interviewed European public sector expert on blockchain, despite early accusations of potential over-hype, many applications are now reaching the services sector market or advanced pilot stage. A 2017 mapping study of blockchain start-ups across the globe identified 115 blockchain start-ups; the authors estimated that the sector was employing around 2,000 people as of 2017, with infrastructure provider start-ups employing a median of 10 people, twice that of application developers (5) or operators (which are the entities that manage or administer a blockchain application or network) (5) (Hileman and Rauchs, 2017a). Of these, over half were based in North America, 28% in Europe (comprising 13% of global people working on blockchain-based activities) and 19% in Asia Pacific (although China filed the largest number of patent applications in 2017, namely, 225 of the 406 patents, compared to 91 from the USA (Thompson Reuters, 2018)). This is in addition to various blockchain initiatives within established organisations (notably in financial services), meaning that the current allocation of resources and number of people employed directly to work on blockchain-based initiatives is likely to be higher. Indeed, as of October 2018, ConsenSys - a blockchain developer and technology services company - reportedly had more than 1,100 staff working globally (ConsenSys, n.d.).

The majority of these start-ups were involved in developing blockchain infrastructure rather than applications for consumer use (Hileman and Rauchs, 2017a). Of these infrastructure providers, half were developing generic blockchain solutions which could be applied in multiple industries, although over 60% also targeted a specific sector as well as, or instead of, offering their solution more widely.

However, start-ups are not the only relevant organisations in the blockchain landscape. The IDC Worldwide Seminannual Blockchain Spending Guide in 2018 forecasts that the worldwide spending on blockchain solutions will reach USD 11.7 (€ 10.31) billion in 2022 (Goepfert and Shirer, 2018).

IDC predicts that Europe will be the second largest investor in blockchain technologies from 2018 to 2022 and will increase its spending from USD 400 (€352) million to USD 3.5 (€ 3) billion (La Croce and Hefny, 2018). If specifically companies with USD 500 (€ 440) million or more in annual revenue are considered, a 2018 survey by Deloitte highlights similar growth trends in blockchain investments.[16] As depicted in Figure 12, almost 40% of respondents indicated that their organisation was planning to invest over USD 5 million (€ 4.39 million) in blockchain technology in 2019-2020 (Deloitte, 2018a); 43% of respondents reported that it was of 'critical' relevance to their organisation and within their top five strategic priorities. Of the organisations polled, 52% indicated that they were focusing on permissioned blockchains, 44% on private blockchains (entirely internal to the company), 44% on public blockchains (such as Bitcoin or Ethereum), and 36% on consortium models.[17]

Figure 10: Expected investment in blockchain for surveyed organisations in calendar year 2019



Source: Deloitte, 2018a. Fieldwork carried out March-April 2018; n = 1053.

2.2.3 Support for the development of the technology

As will be further discussed below, many of the advanced blockchain applications will require a high degree of interoperability between blockchain platforms. It is noteworthy in this regard that much of the development of blockchain technology has progressed as a result of the efforts of open communities exchanging knowledge and using open-source code (including a notable number of white papers (Hofmann et al, 2017)) and large-scale non-profit initiatives. For example, one of the most prominent blockchain platforms is Ethereum, supported by the Switzerland-based non-profit Ethereum Foundation, which is available to non-profit and commercial developers alike (Ethereum, n.d.). Hyperledger, initiated by the Linux Foundation, is another significant effort involving a number of prominent corporate partners (primarily drawn from the financial services and technology industries) to develop open-source blockchain tools for collaboration between companies (Hyperledger, n.d.a). Hileman and Rauchs (2017a) found that a large number of blockchain start-ups made their code open-source, while monetising their offer by providing consultancy or application-development services.

In addition to commercial and social uses, there has been strong governmental interest in blockchain both with regard to potential use in government services and to nurture the technology for economic

[16] The survey polled a sample of 1,053 senior executives in 7 countries (Canada, China, France, Germany, Mexico, United Kingdom, and the United States).

[17] Respondents were allowed to give more than one answer.

advantage more broadly. Twenty-four Member States have signed an agreement to develop a European Blockchain Partnership to cooperate on the development of the technology (European Commission, 2018), and the European Commission has established a Blockchain Observatory (EuBlockchain Forum, 2018). Initiatives are also being implemented at national level: Estonia has employed blockchain-based technology to hold citizen's medical records (e-estonia, n.d.); the Netherlands has undertaken 30 blockchain pilots involving Dutch governmental organisations (Dutch Government, n.d.); and a number of policy initiatives in Malta have been set up to provide a regulatory framework for cryptocurrencies and blockchain adoption (Sanchez, 2018). In Europe, a number of universities have also shown interest in blockchain, with dedicated blockchain and cryptocurrency academic centres established at TU Delft (Netherlands) (TU Delft, n.d.), the Frankfurt School of Finance and Management (Germany) (Frankfurt School of Finance and Management, n.d.), the University of Edinburgh (UK) (University of Edinburgh, 2017), University College London (UK) (UCL, n.d.), Lazarski University (Poland) (Lazarski University, n.d.) and the University of Nicosia (Cyprus) (University of Nicosia, n.d.a), among others.

Box 3. Adoption trends for blockchain (2018-2022)

Given the relatively early stage of adoption of blockchain, definitive sectoral data on their deployment are not yet readily available. However, a recent report on the future of jobs by the World Economic Forum (WEF) provides some indicative data on potential adoption of blockchain from 2018 to 2022. This is based on a survey of companies across the world done over a nine month period (November 2017 to July 2018) with a focus on large multinational companies and other companies which contribute significant revenue and employee size in a local context. The report used Occupational Information Network (O*NET) classifications of the sectors[18], which is retained in the next paragraph to ensure accurate representation of the findings.

Overall, 45% of the participating companies identified blockchain (referred to as distributed ledger (blockchain) in the survey and the report) as a technology they were likely to adopt between 2018 and 2022. When specific services sectors are considered, companies in the financial services and investors (73%), global health and healthcare (67%), and information and communication technologies (67%) sectors reported a higher likelihood of adopting blockchain in comparison to the automotive, aerospace, supply chain and transport (32%), aviation, travel and tourism (37%), and professional services (50%) sectors. 49% of the companies surveyed identified Eastern Europe as a market for the adoption of the technology from 2018 to 2022. For Western Europe, this figure was slightly higher at 54%. Among the European countries for which national-level data are provided in the report, the share of companies identifying France, Germany, Switzerland, and United Kingdom as potential markets for the adoption of blockchain from 2018 to 2022 were 49%, 54%, 50%, and 55% respectively.

The report concludes that to achieve positive outcomes vis-a-vis jobs in the wake of rapid technological change would require an emphasis on lifelong learning, reskilling, and upgrading of individuals' skills across a number of occupational categories. In particular, technology skills as well as non-cognitive soft skills would become more important. Governments would need to upgrade education policies targeted at increasing education and skills levels for all ages; leverage public and private sector partnerships to stimulate job creation; and revise existing tax revenue approaches and social welfare programmes in line with the new economic and business models of work. Industries would need to support upskilling of current workforce to become more technologically skilled;

[18] Occupational Information Network (O*NET) is a database of occupational definitions of work in the USA available online at https://www.onetonline.org/. It was developed under the sponsorship of the US Department of Labor/Employment and Training Administration (USDOL/ETA) in the 1990s. As of 2018, it is maintained by the US National Center for O*NET Development. See Mariani (1999) and National Research Council (2009) for more details.

contribute to building a sufficiently skilled talent pool; and adapt to the increasing influence of the platform economy. The report argues that much as the workers would need to take ownership of their own lifelong learning, the governments and industries would need to support transition and reskilling at work in equal measure.

Sources: Mariani, 1999; National Research Council, 2009; World Economic Forum, 2018b

2.3 Driving forces and barriers

Box 4. Summary of drivers and barriers

- Blockchain is a complex technology, and the applications and public understanding are at very initial stages.
- Drivers of adoption include the potential for new business and economic models and applications based on the transparency, data sharing and auditability enabled by blockchain, and operational benefits such as increased efficiency of exchange processes.
- The ability to build applications on existing platforms or using existing enterprise tools may enable the entry of SMEs into the market without intensive up-front R&D costs.
- Barriers to greater adoption include an unclear legal and regulatory landscape, the need to coordinate multiple parties for advanced applications, the need to develop complex governance and compliance arrangements for multi-party ledgers, and issues related to performance and scalability for some blockchain designs.

2.3.1 Potential drivers for the development and adoption of blockchain

Increased productivity and efficiency to businesses and in the public sector

One of the key driving forces behind the adoption of blockchain is the potential operational benefits for business. As with the wider trend towards increasing digitalisation, proponents of blockchain cite its potential to increase productivity or profit by the automation of organisation processes (for example, relating to data transfer and access); increase system resilience; and make the processing and verification of data more efficient (or partially automated). In a 2018 global survey conducted among business executives, when asked what they believed to be the most significant advantage of blockchain over existing systems in their industry, 32% cited the potential for greater speed compared to existing systems; 28% cited the development of new business models and revenue streams; 21% noted the contribution to security; and 16% cited blockchain's ability to reduce costs (Deloitte, 2018a). As discussed below, blockchain may also provide the opportunity to develop new collaborative models of working and business streams, in addition to enabling new applications, such as smart contracts, cryptocurrencies and advanced Internet of Things applications.[19]

Blockchain-based smart contracts can enable small and medium-sized businesses to better manage their intellectual property and related transactions (de la Rosa et al, 2016). Although blockchain-based solutions are mainly limited to pilots, the technology also has the potential to simplify the small and medium-sized businesses' access to trade finance and lower the costs for order tracking, payments, and record keeping (Batsaikhan, 2017).

[19] The Internet of Things builds out from today's internet by creating a pervasive and self-organising network of connected, identifiable and addressable physical objects enabling application development in and across key vertical sectors through the use of embedded chips, sensors, actuators and low-cost miniaturisation (Schindler et al, 2013).

Blockchain also offers the potential to increase transactional efficiency, operational transparency, and reduced cost of operations in the public sector. Within the EU, a number of Member States are examining the potential of blockchain for delivering public sector services such as tax collection, record keeping of population, land, and healthcare registries, securing and auditing public records, and enabling financial transactions through digital currencies. Most of these uses are at an early trial stage and are in the form of pilot deployments. Key examples include Estonia's e-residency programme which entrepreneurs to start a trusted location-independent EU company online (Republic of Estonia, n.d.), Sweden's attempt at land registration through blockchain (Kempe, 2016), and the UK's trial for social welfare payments distribution through blockchain (Cellan-Jones, 2016). Financial organisations such as the European Central Bank (ECB) (European Central Bank, 2016; European Central Bank and Bank of Japan, 2017), the Dutch Central Bank (Berndsen, 2016), and the Swedish National Bank (Sveriges Riksbank, 2017; 2018) have trialled blockchain-based solutions (including cryptocurrencies) to examine their potential for cost savings, increased transactional efficiencies, and delivering financial services. Beyond these national and regional trials, the European Commission has set up a Blockchain observatory and forum to investigate the use of blockchain technology in a manner compliant with EU legislations and regulatory practices (EUBlockchain Forum, 2018).

Open infrastructure and platforms to build applications

Developments in the technology landscape may also serve to encourage adoption, as well as increase user confidence in and understanding of blockchain technology. Organisations now have the ability to build applications upon existing platforms such as Ethereum and the Bitcoin Blockchain make use of 'Blockchain as a Service' (BaaS) services similar to those offered by Amazon and Microsoft; and make use of business-focused tools, such as those in development by Hyperledger.[20] This may bring the development of blockchain applications within reach of individuals, SMEs and other organisations lacking the in-house R&D capacity to develop the underlying infrastructure. As Iansiti and Lakhani (2017) note, the ability to experiment with single-use applications without intensive, up-front R&D costs will also help organisations to develop skills to consider further, more advanced uses for blockchains. The norm of making platforms open-source may also serve to increase confidence, as organisations are able to understand and interrogate the underlying structures (see, for example, Hyperledger, n.d.b, n.d.c).

Social environment built on trust

Blockchain has also received attention for more radical applications, such as the ability to reshape the social environment towards a state built on trust and cooperative economic models (Manski, 2017; Nascimento et al, 2018) or as an alternative foundational structure for digital communication to the current protocols (the 'TCP/IP' suite) which govern the way that information is exchanged between devices (see, for example, Manski, 2017; Johnson, 2018).

2.3.2 Potential barriers to the development and adoption of blockchain

Despite the interest shown and the developing ecosystem, a number of challenges may hinder or prevent more widespread adoption of blockchain technologies. As shown in Figure 11, barriers reported by respondents to a 2018 global survey of business executives[21] focused on aspects of

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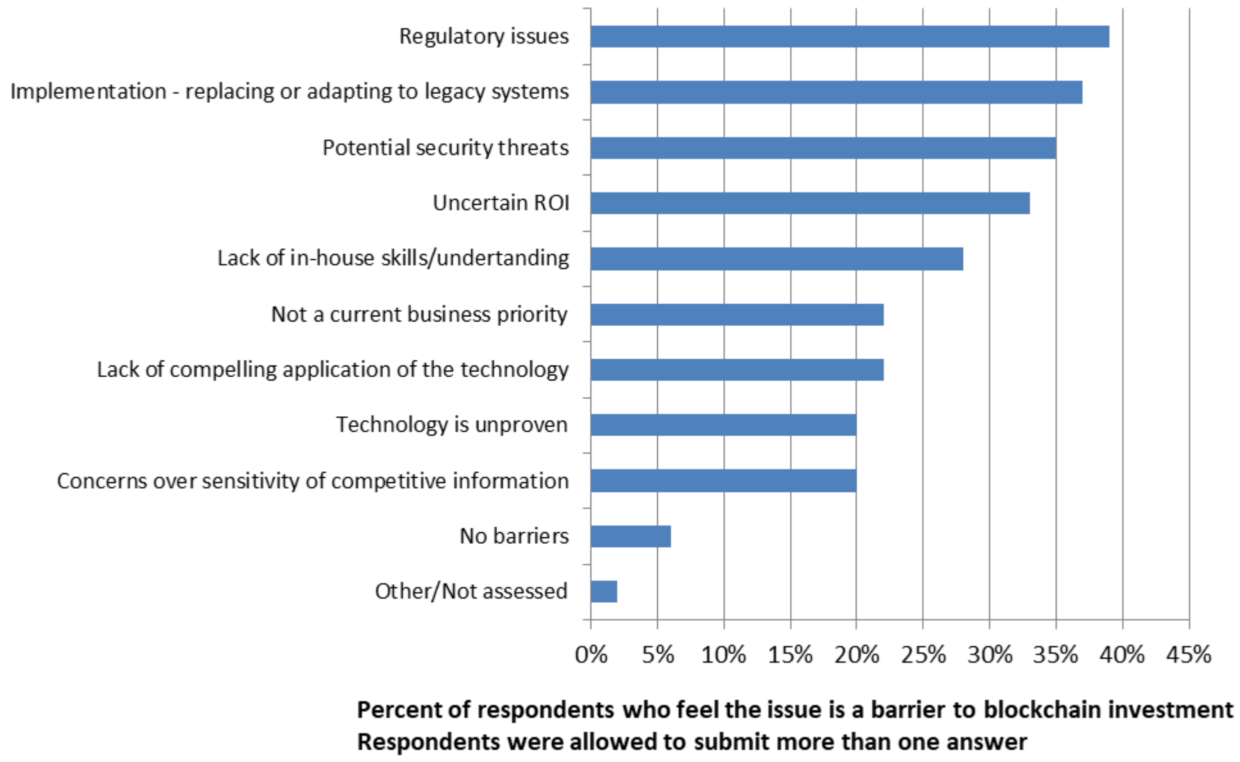
[20] See, for example, Hyperledger (n.d.d).

[21] The total number of respondents was 1,053. The number of respondents from the USA, China, United Kingdom, Germany, Canada, Mexico, and France were 284, 205, 150, 132, 103, 103, and 76 respectively. 26% held the role of Chief Information Officer/Chief Technology Officer; 21% held the role of Chief Executive Officer; 13% held the role of executive vice president; 9% held the role of chief operation officer; 8% held the role of president; 6% held the role of Chief Financial Officer; 5% had other C-level title, 5% held the role of Senior Manager other similar managerial title; 3% held the role of director; 2% were Chief Strategy Officer; and 2% were Business Unit Head or Business President. When a job-level split is considered, 14% respondents were vice president or equivalent and 86% were C-level of equivalent. A C-level executive refers to a high-ranking individual with some responsibility for making company-wide decisions.

implementation, such as regulatory issues, adaptation to legacy systems, security threats and skills, but also, to a lesser extent, a lack of proven use cases relating to the technology (Deloitte, 2018a).

Figure 11: Barriers to implementation of blockchain technology reported by business leaders globally, 2018



Source: Deloitte, 2018a. Fieldwork carried out March-April 2018; n = 1,053.

Complexity of the technology and use cases being at very initial stages

Critically, blockchain is a complex technology to understand (Maupin, 2017; Deshpande et al, 2017). Many use cases remain speculative, and the majority of the public at this stage will not knowingly have engaged with blockchain technology; an interviewed European public sector expert noted that ‘scepticism’ and ‘misconceptions’ remained barriers to adoption. At a more basic level, a lack of agreement on the lexicon employed in the sector and by commentators may also hinder the public understanding of the technology (and thus the understanding of the appropriate use cases and limitations), although efforts are underway at international level to standardise the terminology and taxonomy (this is discussed further below; see also Hanson et al, 2017; Deshpande et al, 2017). This may hinder user and business adoption, as well as a balanced assessment of the potential and technical limitations of the technology - including when a blockchain may not in fact be the most appropriate solution, with some commentators warning of applications proposed for blockchain which have not yet demonstrated viability (Smith et al, 2016; Greenspan, 2015).

According to an interviewed European third sector expert on blockchain, the introduction of large-scale changes to operations (for example, the automation of financial clearing processes) may also run into the difficulties inherent in overhauling organisational processes, including ensuring interoperability with legacy IT systems and the reorganisation of human factors. As a result, early adoption by businesses is likely to take the form of smaller, single-use applications within single organisations (such as identity verification or asset management) (Iansiti and Lakhani, 2017).

Current lack of standardisation

The current absence of technical standardisation may also hinder implementation (Hofmann et al, 2017), thereby risking the development of blockchain 'silos' which are unable to interact with one another (for example, to transfer data across platforms). Hileman and Rauchs (2017a) note that the current blockchain ecosystem remains fragmented, with many of the protocols used by existing blockchains being incompatible (although joint efforts by dominant platforms, such as Ethereum, may go some way towards settling on an industry norm[22]). A standardisation roadmap has been put forward by the International Standards Organization (ISO) covering the period to 2020, to include consideration of standardisation of such topic areas as terminology, taxonomy, identity verification, interoperability, governance, security and privacy, use cases and smart contracts (Hofmann et al, 2017).

Unclear legal and regulatory environment

The nascent state of the technology also means that the legal and regulatory environment remains unclear, both with regard to system design (for example, the way in which data are stored on the blockchain) and with regard to specific applications, such as the legal status and enforceability of smart contracts. It is unclear, for example, how the 'right to be forgotten' or future changes to data protection legislation (for example, the comprehensive changes initiated by the EU GDPR[23]) may interact with the near-immutability of data stored on blockchains (Umeh, 2016), particularly in the case of permissionless ledgers, which require the coordination of multiple independent parties to revise the ledger.[24] Blockchain industry respondents to a 2017 global survey on potential challenges to sector development identified privacy and confidentiality concerns as more of an issue than technical issues relating to performance and scalability, and they highlighted the unclear legal and regulatory environment most often (Hileman and Rauchs, 2017a). For this reason, some commentators have called for the establishment of regulatory 'sandboxes' (special agreements with regulators which permit the piloting of technology under set conditions and without legal risk) for blockchain (see Maupin, 2017; Nascimento et al, 2018). As Lyons (2018) notes, the EU experience of developing complex, cross-border regulation and policy may be an advantage with regard to future regulation of blockchain (although, as one interviewed European third sector expert noted, the pace at which EU legislation is developed may be outpaced by the development of blockchain itself). The development of appropriate regulation itself may also be a challenge for regulatory bodies which may need to marry technical understanding of blockchain with the specific needs of the regulated sector with regard to such practices as data sharing and dispute resolution (Grech and Camilleri, 2017). However, even with appropriate expertise, the siloed nature of current regulatory bodies (for example, by sector or country) and the status of blockchain as a transnational, multi-sectoral foundational technology may hinder the development of appropriate and meaningful regulatory regimes (Maupin, 2017).

Unclear governance structures for underlying ledgers

The governance of both permissioned and permissionless ledgers may pose challenges to implementation. As blockchain nodes must coordinate in order to 'agree' on the content of a ledger,

[22] Indeed, Hyperledger and the Ethereum Enterprise Alliance, another prominent enterprise community focusing on developing business-oriented open-source standards for the Ethereum platform (Enterprise Ethereum Alliance, n.d.) announced in October 2018 that they will collaborate on developing open-source standards to avoid the risk of silos (Allison, 2018).

[23] This was cited by one interviewee (a European academic expert) as a significant challenge for the sector; however, another interviewee with expertise on the third sector felt that this would not be a problem in the long term, as solutions would be developed to mitigate this.

[24] See Nascimento et al (2018) for an extended discussion of privacy and data protection concerns relating to the storage of data on a blockchain.

so, too, must the controlling parties of those nodes 'agree' in order to develop and maintain the blockchain, such as agreeing on the terms of use, making necessary corrections or edits to earlier blockchain data and ensuring software updates are correctly and adequately installed. While this may be simple for single organisations that control all the nodes, agreeing and respecting the terms of governance may be more difficult among consortia or wider sector parties, and is likely to require the establishment of 'off-chain' agreements and terms of reference. Projects such as Hyperledger have also aimed at creating a community of developers with overarching structures in place (controlled by the community at large) with responsibility for maintaining the framework (Behlendorf, 2016). In the 2018 global survey of business executives, 75% of respondents either already participated in a consortium or were likely to join one, 13% were considering launching their own, and just 7% were planning to 'go it alone' (Deloitte, 2018a). One interviewed European public sector expert noted that they were 'impressed with the variety and diversity' of the initiatives.

Challenges related to performance and scalability of blockchain

According to some interviewees[25], a number of technical issues (for example, the high energy use of some public blockchain designs,[26] incentivising actors to maintain the blockchain in permissionless models and ensuring the scalability of a blockchain platform) and perceptions of the technology's maturity may also hinder the further development of the technology. However, private or permissioned ledgers may be better able to set appropriate parameters with regard to the functioning of the ledger to address performance needs; in the 2018 global survey of business executives, 84% agreed that blockchain technology is 'broadly scalable' and will reach mainstream adoption (Deloitte, 2018a).

2.4 Potential applications in the services sector

Box 5. Summary of potential applications in the services sector

- Blockchain technology could enable a range of functions, such as identity verification, payments, 'timestamping' (recording the time at which an event occurred) and data sharing, which are applicable to various service sectors.
- Early and strong interest has been shown by the financial sector, and prominent use cases have also been proposed for the education, logistics/supply chain, health, media and public service sectors.
- The likelihood and timescale of adoption of blockchain for a particular purpose may depend on the extent of coordination required between multiple (public or private) partners and on the novelty of the application.

Blockchain technology may have applications for organisations or coalitions which rely on the secure storage, verification and sharing of information (such as data or asset ownership status), particularly when involving multiple stakeholders or in the absence of a trusted or efficient intermediary. The

[25] Based on separate interviews with an European public sector expert and an industry expert

[26] Although difficult to estimate, the power consumed by Bitcoin mining is understood to be considerable (Wired, 2017); for this reason, many mining pools for Bitcoin are concentrated in geographies with cheap energy costs (notably China and Iceland), raising concerns as to interference by a state actor if over 50% of the computing power were to be concentrated in their territory. However, new models of public blockchain have also sought to address this by different consensus models, including 'proof of stake', in which the blocks are not added by solving a mathematical problem (as in Bitcoin) but, rather, as a result of the amount of platform token held by the miner. See Hileman and Rauchs (2017).

nature of the service sector as heavily reliant on information and knowledge exchange; data processing; and, increasingly, digital communication and transactions means that the majority of use cases to date have focused on the service sector.

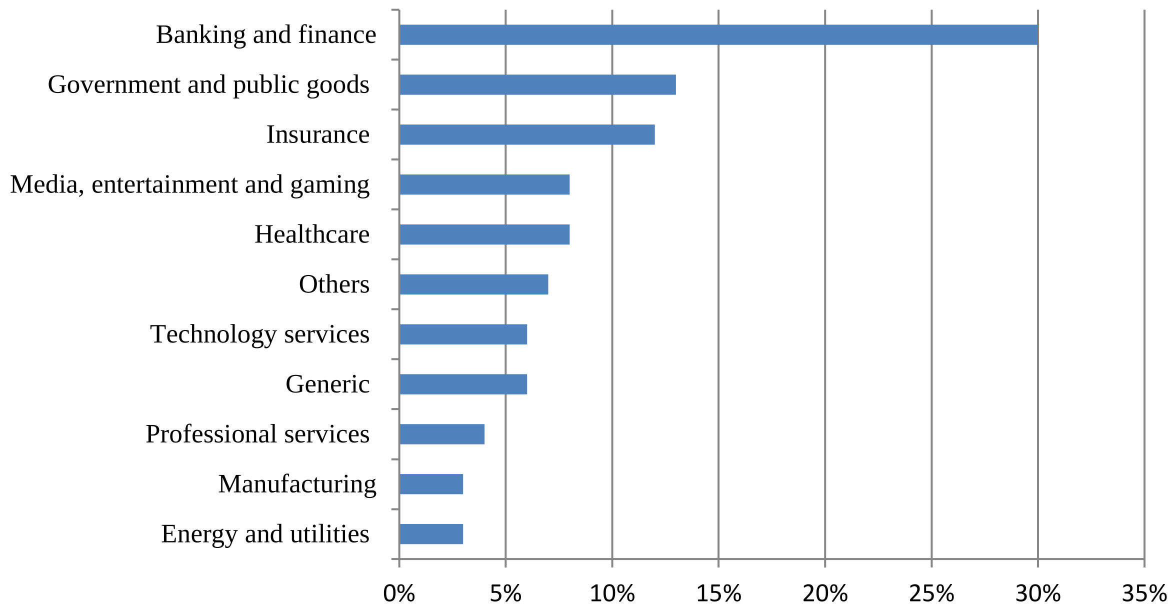
As Staples et al (2017) note, the benefits of blockchain for European organisations are likely to be found in the potential efficiency savings and innovations to products and business models. In this regard, many of the potential benefits of blockchain are not sector specific, although some sectors may find particular value in different applications (as discussed below). Some key functions enabled by blockchain technology may include:[27]

- **Tokenised asset exchange and cryptocurrencies:** Blockchain could enable the transfer and verification of ownership of assets, including cryptocurrencies and tokens representing off-chain assets (such as art or property).
- **Governance/decision making**: Through the use of private keys, blockchain could enable an online voting system (and, in the case of smart contracts, with some decisions automatically enforced) (Boucher, 2017).
- **Advanced Internet of Things applications:** By enabling the sharing of data across different applications, blockchain could enable data sharing across connected items and thus advanced and decentralised Internet of Things applications (Tapscott and Tapscott, 2016; Nascimento et al, 2018).
- **Identity verification**: Through the use of private keys unique to individuals, blockchain could enable a platform for identity verification, according to an interview with an European public sector expert (see also GOST, 2016) and consequently the use of this verified online profile to interact with other applications.
- **Document and certificate verification**: Blockchain could enable the storage of documents or certificates with access controlled through private keys (Grech and Camilleri, 2017).
- **Audit and '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) (ESMA, 2017).
- **Data handling and storage**: Blockchain could enable the storage and sharing of data between organisations and applications (Smith et al, 2016).

Figure 12, Figure 13 and Figure 14 draw from the blockchain landscape mapping study conducted by Hileman and Rauchs (2017a) to offer an indication of current interest among various service sectors. As shown in the figures, many of the use cases, customers and target markets relate to different aspects of the financial services industry, although some interest in developing applications for other sectors, including the public services sector and media/entertainment sector, is apparent. As shown in Figure 12 and Figure 13, cross-sector uses - including 'generic', digital identity and supply chain use cases - are also a sizeable minority.

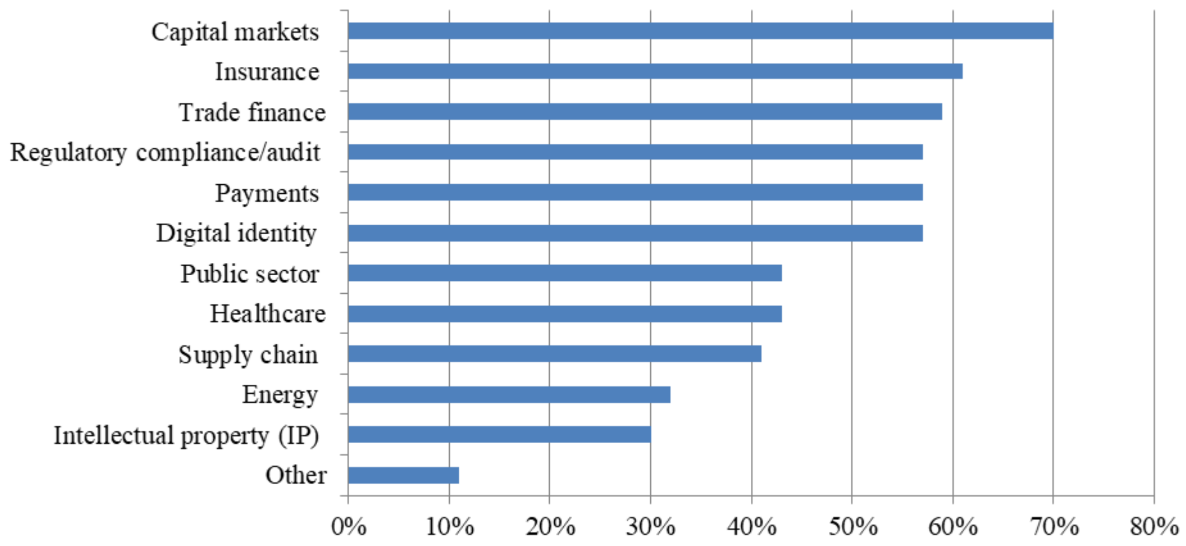
[27] These blockchain-enabled functions are not sector-specific.

Figure 12: Percentage of global use cases[28] identified in public discussion, press releases and reports



Source: Hileman and Rauchs, 2017a; based on 132 use cases identified by the study authors from public discussion, reports and press releases.

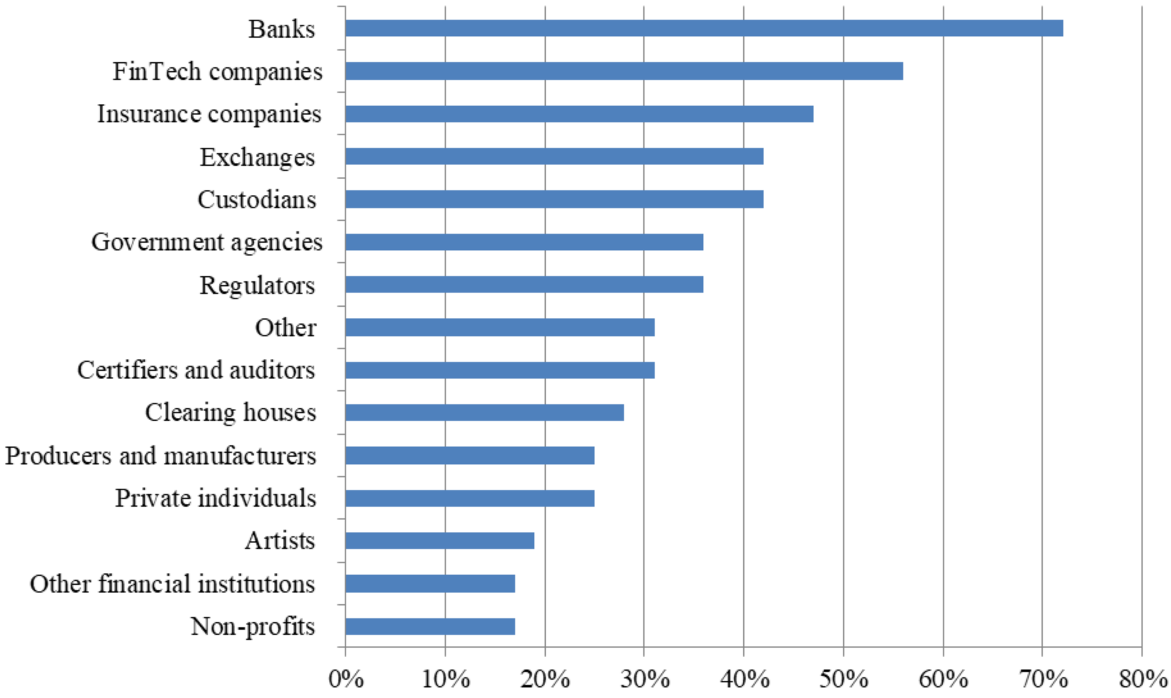
Figure 13: Percentage of blockchain service providers targeting different sectors/use cases



Source: Hileman and Rauchs, 2017a; based on a sample of 44 enterprise survey respondents. Respondents could select more than one sector/use case.

[28] The term use case, when used in this way, is understood as a term which 'describes how a user uses a system to accomplish a particular goal' (Techopedia, n.d). It is often used as a synonym for application.

Figure 14: Percentage of blockchain providers with customers in different industries

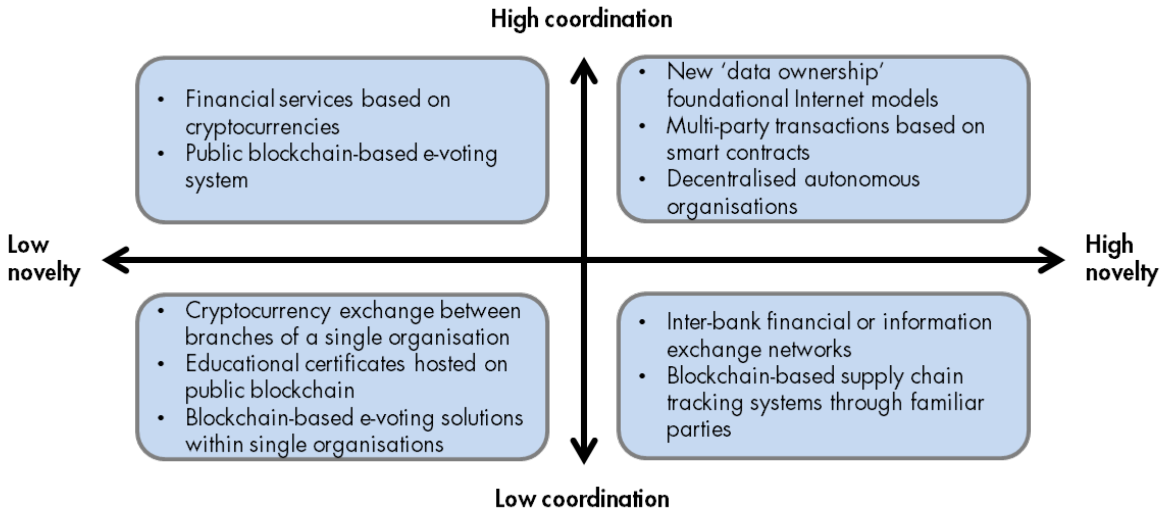


Source: Hileman and Rauchs, 2017a; based on a sample of 44 enterprise survey respondents. Respondents could select more than one industry.

Iansiti and Lakhani (2017) identify four types of blockchain applications, based on the degree of novelty (that is, the change it represents to current models of social and economic organisation) and the number of parties required to coordinate the activity:

- **'Single-use' applications** which are low-novelty (therefore not requiring significant change to current business models) and require low levels of coordination between multiple partners. Examples are Bitcoin and emails, for which exchange requires the coordination of two parties but in which the applications represent only a marginal change to existing models (for example, digital credit card payments, post).
- **'Localisation' applications** which are high-novelty but require only a limited number of users, such as private blockchain networks between financial services organisations.
- **'Substitution' applications** which are low-novelty but require a high degree of coordination between parties and thus face greater barriers to adoption. The authors offer the example of a full-blown cryptocurrency system which, unlike simple Bitcoin transactions, may involve multiple public bodies. A further example may be the introduction of a blockchain-based e-voting system for public elections (Boucher, 2017).
- **'Transformational' applications**, which could fundamentally alter social or political organisation but would require the overhaul of existing institutional structures and patterns of behaviour, thereby facing significant barriers to adoption. The authors cite two examples which may deliver particular value, but would require the coordination of multiple public and private actors to initiate: a comprehensive identity verification system able to be used for different state and private functions, and an integrated financial ledger which enables algorithmically driven money laundering.

Figure 15: Types of blockchain applications



Source: Authors' elaboration, based on Iansiti and Lakhani, 2017.

The authors note that, due to the difficulty of coordinating multiple actors, the transformative applications, although delivering significant value, will also take off last, while single-use applications within firms - for example, those representing an efficiency benefit over an existing process - are likely to emerge in the shorter term. While this may be the case also for other technologies, the nature of blockchain, in which many advanced applications will rely on the coordination of multiple parties, means that this may be particularly relevant when thinking about the development trajectory of the technology.

2.4.1 Financial services

For the financial services sector, for which the organisation of value exchange is the *raison d'être*, the potential of blockchain as a facilitator for value storage and exchange is of clear relevance and, accordingly, some of the keenest interest has been shown by financial firms and consortia. In the blockchain mapping study by Hileman and Rauchs (2017a), established financial services firms reported focusing primarily on blockchain applications for digital identity verification and regulatory compliance, while start-ups were focusing instead on applications for capital markets.

Notably, blockchain has been proposed as a means of coordinating bookkeeping across organisations by creating a shared ledger of ownership, thereby avoiding the need for organisations to separately update their records and finalise other legal forms to confirm the transfer of legal ownership of an asset (such as stock transfers), which can take multiple days following a transaction (Iansiti and Lakhani, 2017; Barclays, 2016). Blockchain applications may also enable better recording and safekeeping of assets; and the collection and compilation of data for reporting and regulatory requirements. They may even enable 'automated' regulatory compliance and know-your-customer (KYC) processes; increase system resilience; reduce transaction risk by rendering transactions immediate; enable 24-hour operations (for example, for stock trading); and otherwise reduce operational costs for business by automating backroom processes (ESMA, 2017). Table 3 provides an overview of the ways that blockchain capabilities may affect key functions of the financial sector.

Table 3: Potential implications for functions in the financial sector

Function	Potential benefits of blockchain-based systems	Affected stakeholders
Authenticating identity and value	Verified identities for interacting with financial services	Rating agencies, consumer data analytics, marketing, retail banking, payment card networks, regulators
Moving and transferring value (for example, payments)	Reduction in cost and speed for transferring value	Retail banking, wholesale banking, payment card networks, money transfer services, telecommunications, regulators
Storing value (including currencies and commodities)	Robust store of value through digital assets	Retail banking, investment banking, asset management, telecommunications, regulators
Lending value to other parties	Individuals and organisations can issue, trade and settle debt using blockchain tokens; provides a history of payments to increase reputation	Wholesale, commercial and retail banking, public finance, microlending, crowdfunding, regulators, credit rating agencies, credit score software companies
Exchanging value with other parties	Increased speed of settlement of trades by immediate value exchange	Investment banking, wholesale banking, foreign exchange traders, hedge funds, pension funds, retail brokerages, clearing houses, stock and futures, commodities exchanges, commodities brokerages, central banks, regulators
Funding and investing in an asset, company or start-up	New peer-to-peer financing models; new models of automatic dividend payments through smart contracts	Investment banking, venture capital and other providers of start-up capital, legal audit, property management, stock exchanges, central banks, regulators
Insuring value and managing risk	Better analysis of risks of certain insurance policies for the insurance firm using reputational systems; decentralise markets for insurance	Insurance, risk management, wholesale banking, brokerages, clearing houses, regulators
Accounting and corporate governance	Clear and transparent record keeping for audits and reporting	Audit, asset management, shareholder watchdogs, regulators

Source: Taken (minimally adapted) from Tapscott and Tapscott, 2016.

As in other sectors, the adoption and application of blockchain will depend on existing processes, institutions and collaboration among sector players. For example, Table 4 provides an indicative timeline suggested by J.P. Morgan and Oliver Wyman (2016) as to how the adoption of blockchain could evolve specifically for functions in the asset management sector.

Table 4: Projected timeline of changes in asset management services

Information sharing, 2016-2019	• Sharing and communicating data • Used internally and between trusted organisations • Augmentation of existing processes
Data solutions, 2017-2025	• Storage and analysis of data • Incorporation of blockchain as part of existing solutions, supporting new efficiencies • Multiple blockchain infrastructures to select from
Critical infrastructure, 2020-2030	• Adopted by market as main infrastructure for critical functions, but with centralised authority (for example, granting access rights) • Replacement of key functions, such as asset and payments infrastructure
Fully decentralised (timeline uncertain)	• Replacement of central infrastructure with full decentralised solutions • Direct engagement by organisations and individuals in asset transactions • Effective legal and regulatory infrastructure • Fully enabled digital fiat currency and peer-to-peer (P2P) economic models

Source: Based on J.P. Morgan and Oliver Wyman, 2016.

However, the use of blockchain in financial services may face specific challenges, relating in particular to the stringent regulatory and legal environment, which requires a high level of trust, verification and authentication among partners (ESMA, 2017), and the large volume of transactions that characterise the sector. In a three-year pilot of the use of blockchain technology for financial transactions, the Dutch central bank (De Nederlandsche Bank, DNB) concluded that, while promising, none of the five prototypes for a digital currency piloted were able to effectively balance the need for a highly secure, resilient system with the need for cost-effectiveness and efficient use of energy to currently meet the needs of financial markets (Nederlandsche Bank, 2018).

The experience of the Dutch Central Bank also highlights two key challenges to wider adoption of blockchain in the financial services industry: interoperability amongst the different solutions and high energy consumption requirements (see also Atos, 2018). As a distributed, decentralised technology, blockchain does not have a centralised governance system (Deshpande et al, 2017) for either the development of the technology or the solutions based on it. As a result, there are multiple, often incompatible implementations of blockchain available on the market. The resulting lack of interoperability poses challenges to the adoption of the interconnected financial services industry which has a number of existing protocols for tracking, auditing financial transactions based on the

ISO 20022 standard.[29] As part of this standard, the financial services sector has well-established protocols as Financial Information eXchange (FIX) which facilitates trading of equities[30], FpML (Financial products Markup Language) which enables electronic trading and processing of derivatives[31], and the Society for Worldwide Interbank Financial Telecommunication (SWIFT) protocol which enables messaging services and information transfer between financial institutions.[32] These protocols rely on a system of intermediaries to detect fraud and money laundering and ensure compliance with local laws and regulations. Since one of the main defining attributes of blockchain is disintermediation (that is, reducing intermediaries), in the medium and long-term, any blockchain solutions being developed for the financial services sector would have to co-exist with legacy systems which are compliant with the existing legislation and regulation (Deshpande et al, 2017). This has significant cost implications for most businesses and financial institutions since the blockchain solutions currently available are mostly in the form of proof of concepts and the case for return on investment on them is not yet proven (Higginson et al, 2019).

The other key challenge facing blockchain implementation in the financial services sector is the absence of a consensus mechanism (protocol or standard) which can enable the high volume transaction processing critical to the existence of global financial services institutions. Current blockchain solutions consume large amounts of energy, are resource intensive in terms of computing power, and unproven in terms of performance scalability (Atos, 2018). Although blockchain offers a number of potential advantages in terms of security, robustness, and transparency, whether it can be a cost-effective solution as part of enterprise-level deployments remains to be seen.

2.4.2 Education

Another sector which has seen early and strong interest in blockchain is the higher education sector. One particular use case is to encode education, professional qualification 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 certificates (which can be easily lost or forged) or contacting the issuing institution. A number of initiatives in this area have launched, including Blockcerts (developed by the Massachusetts Institute of Technology (MIT)), an open-source platform and standard to enable the development of certificate-based apps, and the development of certificate hosting and validation systems by such organisations as Sony Global Education (Hyperledger n.d.e) and the University of Nicosia, who use the Bitcoin blockchain to issue degree certificates (see case example 2 in chapter 5). Using the framework by Iansiti and Lakhani (2017), this can be understood as an application which requires low coordination (as certificates can be issued and verified by single organisations) and is low novelty (by replacing an existing process of certificate verification), which may help to explain the early adoption.

Other use cases proposed for the education sector include better management of personal data, potentially through better identification verification; the use of 'timestamping' to better validate intellectual property rights, as the basis for 'open' academic publications; and the creation of self-governing, decentralised communities of higher education stakeholders to manage institutional accreditation standards. Table 5 provides an overview of the predicted timeline for some example use cases in education.

[29] See https://www.iso20022.org/ for further information

[30] Further information on the FIX protocol is available at https://www.fixtrading.org/what-is-fix/

[31] Further information on FpML is available at http://www.fpml.org/about/what-is-fpml/

[32] Further information on the SWIFT protocol is available at https://www.swift.com/about-us/discover-swift

Table 5: Potential use cases in education

<table>
<tr><th>Timeframe</th><th>Use case</th><th>Barriers</th></tr>
<tr><td>Present</td><td>• Using blockchain to securely store records
• Receiving payments from students via blockchains</td><td rowspan="4">• Lack of current standardisation of educational certificates, including standards for computer-readable data
• Emerging ecosystem of third-party providers (for example, wallet providers, trading platforms) prevents true disintermediation, reintroduce issues with dependence on central authority
• Technical issues, including energy use and scalability</td></tr>
<tr><td>Short term</td><td>• Using blockchains to verify multi-step accreditation</td></tr>
<tr><td>Medium term</td><td>• Using a blockchain for automatic recognition and transfer of academic credits
• Using a blockchain as a lifelong learning passport
• Blockchain for tracking intellectual property and rewarding use and re-use of that property
• Using Verified Sovereign Identities for Student Identification within Educational Organisations</td></tr>
<tr><td>Long term</td><td>• Providing student funding via blockchains, in terms of vouchers</td></tr>
</table>

Source: Based on Grech and Camillieri, 2017.

2.4.3 Logistics and retail sectors

The ability to keep a secure and to all intents and purposes immutable record of data means that provenance and ownership tracking and supply chain management in the retail sector have arisen as a key application of blockchain technologies. Currently, goods may pass through multiple ‘caretakers’ along the course of a supply chain (including producers, transit companies, intermediary producers, retailers and end users). By using individual asset codes to securely and transparently track an individual item through different owners (such as a garment, foodstuff or resource), blockchain could reduce the vulnerability to theft and double-accounting (by ensuring that goods are one-in-one-out) and increase the transparency of the item’s provenance (see case example 3 in chapter 5 for more details).

Similarly, a number of use cases for tracking the ownership of assets have been suggested. Tapscott and Tapscott (2016) identify land titling as a clear use case for blockchain, particularly in countries in which land titles may be a primary source of credit, but for which the administration of titles is open to corruption. Everledger, a UK-based company, uses a blockchain to record ownership and log identifying features of luxury goods, notably diamonds, for which the market is vulnerable to stolen diamonds re-entering the market with fake ownership and provenance records (Everledger, n.d.). In both cases, by using the blockchain primarily for its immutability and by retaining a degree of central control over the administration, the ledgers in question are both low novelty (in that they are digitising an existing process) and require low coordination.

It should of course be noted that blockchain-based records may only be as good as the information logged on the system; blockchain-based land titling, for example, may not be of use if clear ownership cannot be established in the first instance, while stolen diamonds can be re-cut to remove identifying features and re-enter the market at lower risk of identification, or be registered with fraudulent papers from the outset.

An interviewed European third sector expert also noted that the development of a secondary market in asset-backed tokens (for example, a token representing a real estate asset) would continue to be a major trend in the coming years, given their ability to simplify, through smart contracts and automation, what would be costly procedures in the 'real world'. In this regard, the interviewee noted that tokenised assets traded on a secondary market represented 'very liquid and accessible investments' compared to traditional methods: 'The old school and crypto world will mix'.

2.4.4 Healthcare

A number of different potential uses have been mooted for blockchain in the health sector, such as the automated reporting of clinical trial protocols and results (Smart Contracts Alliance in collaboration with Deloitte, 2016); the tracking of prescriptions; Internet of Things (IoT) applications and patient-wearable devices enabled by blockchain; supply chain management and tracking of faulty batches for recall; and verification of medical professional identity and qualifications (Deloitte, 2018b).

Given its core use as a database, an interviewed European public secotr expert noted that blockchain has received particular attention in the healthcare sector for its potential use in storing and sharing medical records (see also Krawiec et al, n.d.). Medical records, by nature, are highly sensitive and private documents for which access must be tightly controlled, but which may need to be shared with multiple parties to ensure quality of care (such as medical, ambulance, insurance, social care and police services). On the other hand, the widespread sharing of anonymised data may have benefits for medical research and business innovation. For this reason, blockchain has been suggested by some parties as a means by which to share health records or health data between stakeholders, while also retaining a high level of security and protection from fraud by enabling individuals to control access to their records and providing a transparent record of access by others.

For example, one existing example of the use of blockchain in the health sector is Estonia's use of blockchain technology (provided by the commercial company Guardtime) to secure health records (e-estonia, n.d.). Health records of citizens are stored on a separate database, with records of access and alteration stored on a blockchain along with the identity of the person making the change (facilitated by the national e-identification card) (Gemalto, 2017), thus providing a record in case of data breaches, illegal access or unapproved changes to the record. Patients, by logging in to the system, are also able to check who has accessed their records.

In another example, My Health My Data (MHMD) is a Horizon 2020-funded project implemented by a consortium of European hospitals, universities and commercial companies, which aims to use blockchain to prototype an open biomedical 'data marketplace'. Under the proposed model, patients would be able to control access to their anonymised and encrypted health records by granting consent for different levels of access through multi-level encryption. In doing so, the project aims to explore whether a blockchain-based system would enable the greater sharing of data for mutual benefit through research, while improving data protection by avoiding the need to transfer data between local data repositories, with multiple points of vulnerability for fraud and cyberattacks (My Health My Data, n.d.).

2.4.5 Public services

Public services comprise a large body of different activities, but often with shared concerns about ensuring value for money, a level of transparency and the security of critical systems. The prospect of efficiency gains as a result of blockchain has also garnered attention with regard to the potential application of the technology in delivering various public services. One interviewed industry expert noted that the appeal would also be for the sake of promoting innovation and the consequent economic growth, rather than for particular use cases, as initiating government projects would help to establish the national ecosystem.

For example, a report by the UK Government Office of Science and Technology (GOST) lists a number of potential applications in the public services sector, such as capitalising on the resilience of blockchain ledgers to protect critical infrastructure; increasing financial inclusion while enabling greater tracing and management of welfare support; transparency in aid money chains; and reducing tax fraud by means of automated VAT procedures, as noted by an interviewed European public sector expert (see also GOST, 2016). Hileman and Rauch (2017) found in a study of 57 public sector organisations that a number of different use cases were being investigated, with half of the organisations polled reporting that they were exploring the application of blockchain for identity and ownership records management, while central banks were focusing on the prospect of central bank-issued digital currencies and payments. Of the public sector institutions included in the sample, half (49%) were from Europe, more than double the proportion for the next region (Asia Pacific, with 23% of participants).

However, the use of blockchain in the public services sector may also face particular challenges relating to the need to demonstrate value for public money and meet high ethical standards. In 2016, the UK government ran a small-scale pilot to examine the viability of a blockchain-based system for distributing social welfare payments.[33] Few details about the trial are available, and in June 2018, the government announced that the pilot had proven unviable due to the expense and limited take-up potential (Hansard HC Deb, 7 June 2018). In the mapping study by Hileman and Rauch (2017), the key challenges reported by central banks were immature technology, confidentiality issues and an unclear regulatory framework. While other public sector institutions were on the whole slightly more confident about overcoming various challenges than were central bank respondents, they cited an unclear regulatory framework, potential issues with data protection laws and immature technology as the key challenges Hileman and Rauch (2017). One interviewed European third sector expert considered that adoption would be slow until a larger number of use cases were apparent in the private sector.

Perhaps more speculatively, blockchain has received attention as a potential foundation for an e-voting system (Boucher, 2016, 2017). The main drawback of e-voting systems is the vulnerability to cyberattacks or manipulation of results; while the convenience of e-voting systems may trump the risk for low-stakes elections (for example, corporate elections), this is a more significant challenge for national-level elections (with Estonia as the only EU Member State with a currently operational e-voting system) (Trechsel et al, 2016). However, the nature of blockchain as a near-immutable data record with no centralised point of control (and thus low vulnerability to cyberattack or manipulation) could enable a voting method in which voters can verify that their ballot has been cast; states can verify that no voter has cast their e-ballot twice; and observers can verify that the results have not been manipulated by state or other actors.[34]

[33] Ethical concerns were raised by some about the privacy implications; see Cellan-Jones (2016).

[34] One potential challenge in this regard is ensuring that the content of the ‘ballot’ - the preference indicated electronically by the voter - has safeguards against any possible decryption, in order to meet legal requirements for ballot secrecy. See Smith et al (2016) for a more in-depth discussion on data storage on a blockchain. For a wider discussion on the benefits and drawbacks of internet voting in elections and the relationship to wider electoral administration, see Faulí et al (forthcoming).

Box 6. Blockchain, Internet of Things, big data, and autonomous road vehicles: A cross-technology perspective

Blockchain enables storage, access, and transfer of data in digital format and thus has the potential to be used in conjunction with a number of 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 relation to IoT applications, blockchain is primarily being considered for strengthening the security of IoT platforms and cloud infrastructures (Kshetri, 2017). In particular, the use of blockchain platforms such as Ethererum has been tested to build smart contract capabilities in IoT devices and strengthen the cryptographic and security features of such devices (Huh et al, 2017). Blockchain's capabilities to store and maintain data in a distributed manner are highly relevant to the healthcare sector in which confidentiality of patient data and ensuring secure access to specific personnel is of critical importance (Liu, 2016; Cole, 2018). With the use of wearable devices expected to increase in the healthcare sector, blockchain-based solutions are also expected to enable data storage and management of electronic health records in conjunction with wearable devices (Mettler, 2016; Pilkington, 2017). In relation to autonomous road vehicles, the use of blockchain for specific real-time outcomes such as refuelling, energy recharges, and payment transactions has been suggested as possible scenarios where blockchain-based solutions could play a key role in the future (Pedrosa and Pau, 2018; Yuan and Wang, 2016). The use of blockchain in VR/AR applications is considered to have potential mainly in relation to distribution of gaming, streaming content through a decentralised platform enabled by cryptocurrency payments (Wood, 2018). However, despite the suggested potential, the use of blockchain in relation to VR/AR is at a very early stage and thus yet to see broader commercial interest.

Source: Cole, 2018; Huh et al, 2017; Kshetri, 2017; Mettler, 2016; Pedrosa and Pau, 2018; Pilkington, 2017; Wood, 2018; Yuan and Wang, 2016

3. Potential socioeconomic implications of blockchain

Below, some key views from the literature on the potential implications of blockchain on the services sector are presented. It is important to note that these trends will not occur in isolation, but are subject to other megatrends, such as the use of wider digital technology, and demographic trends that may affect the working environment (see, for example, WEF (2016)), with consequent shifts in organisation and productivity.

3.1 Implications for productivity and outputs

Box 7. Summary of implications for productivity and outputs

- Blockchain platforms may enable new methods of collaboration between organisations based on a shared data layer, with consequences for the role and nature of intermediary service providers.
- Through the use of smart contracts and internal/sector currency tokens, blockchain technology could enable the automation or streamlining of business processes, with associated implications for productivity and internal organisation.
- 'Initial coin offerings' (ICOs) may offer a new method of crowdfunding and attracting investment for organisations by enabling the advance sale of services or shares in profits to interested customers.

3.1.1 Sector collaboration

One of the projected changes as a result of wider adoption of blockchain technology relates to changing models of industry and sector collaboration.

The ability to create shared ledgers and automate key functions often implemented by intermediaries may enable greater direct collaboration between organisations on information sharing and value exchange, including across national borders. In addition to efficiency savings through the improvement and automation of processes, this may enable additional functions, such as analysis of securely pooled datasets (see, for example, Hyperledger n.d.b) and mechanisms for collective verification of identity without the need for additional, third-party intermediary institutions. However, the development of private ledgers among networks of businesses (such as financial consortia) may also raise barriers to market entry for new organisations unable to take advantage of the efficiencies and knowledge exchange enabled by the shared ledger (Hanson et al, 2017), potentially increasing the risk of cartelisation behaviour.

However, despite the mooted potential for blockchain to replace intermediaries, the reality of coordinating multiple parties in order to introduce the more advanced, cross-sectoral applications means that third-party organisations may not disappear in the near future. Many offer complex services which rely on intimate sector knowledge and high skills sets; it is easier, for example, for financial clearing service businesses to adopt blockchain as part of their offer than for banks to coordinate to create a functional ledger to replace the clearing process entirely.[35] Third-party intermediaries may be able to capitalise on their own status as a trusted organisation to minimise concern about the introduction of blockchain technology into processes, particularly in cases in which large-scale, high-coordination (and thus potentially high-risk) efforts would be needed for more transformative applications.[36] Equally, organisations which enable the transfer of ownership of tokenised assets still require an intermediary to store and potentially physically transport goods and to guarantee and enforce contracts. Other ways of monetising blockchain services in the developing ecosystem - with consequent development of service providers - may include commercial application development; consulting services; providing ‘enterprise’ versions of free software; charging fees for the maintenance of a network; acting as the ‘gatekeeper’ to a network; and providing professional support and training (Hileman and Rauchs, 2017a).

Whether or not some institutions may disappear or be undermined as a result of the automation of their services by blockchain, new third-party organisations which provide services relating to the governance and operation of shared sectoral ledgers may arise. For example, the Learning Machine app, based on the Blockcerts platform, offers a qualification verification service. In this case, the model is funded by the issuing institution, while the owner of the certificate and the party wishing to verify the credentials can access the service for free (Grech and Camilleri, 2017). The authors who studied the Learning Machine app note that many applications will depend on utilising existing elements of the blockchain service layer (for example, wallet providers in order to hold and trade tokens) - thus leading to the emergence of a new class of intermediary organisations as a fundamental part of the blockchain landscape.

3.1.2. Smart contracts

One aspect of blockchain may be the use of ‘smart contracts’ to enable instant transfers of information or assets between parties. Smart contracts are self-executing codes which, upon confirmation that

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[35] For example, the Liquidity Alliance Ledger project is a project by four international central securities deposits, in Norway, South Africa, Canada and Luxembourg, to increase transparency in cross-border securities transactions (Hyperledger, n.d.b).

[36] As the CEO of Eurex Clearing, the clearing house for Deutsche Börse Group, requested a joint effort to introduce blockchain technology to post-trade processing, ‘Through the involvement of [Eurex Clearing] as a trusted third party, a clear set of rules and governance would be ensured’ (Hyperledger, n.d.b.).

certain criteria have been met, are able to automatically alter the information stored on the ledger (for example, by transferring ownership of a token) (Fawcett et al, 2018).[37]

The concept of a smart contract predates blockchain, and the term was first used in 1995 (Szabo, 1995). The vending machine is highlighted (Smart Contracts Alliance in collaboration with Deloitte, 2016) as an early example of a smart contract in which the meeting of one criterion (the input of sufficient money) results in the execution of an activity (the dispersal of the vending item). However, the automated nature of such contracts, in which the terms are enforced by algorithms rather than intermediaries, has found particular favour with regard to further enabling highly decentralised and machine-to-machine blockchain applications.

In this regard, smart contracts can allow more complex transactions in a ledger ecosystem - transactions which go beyond simple, one-to-one value exchange, to enable applications in which the data recorded in the blockchain database are altered according to a set of more complex conditions (Fawcett et al, 2018; Nascimento et al, 2018). In enabling smart contracts, blockchain may facilitate the automation of a number of processes currently performed as a result of complex human activity and involving the input of various third-party intermediaries. Davidson et al (2018) characterise this as the ability to 'carve out those parts of firms that can be rendered as complete contracts where they lower transaction costs… increasing the range to which economic coordination can extend into the future'. [38] In this regard, the reduced cost of contracting could also enable firms to outsource more of their core functions as discrete tasks to external providers (OECD, 2018c). A white paper by the US Chamber of Digital Commerce identified a number of example use cases for smart contracts which could automate various processes currently performed by organisations (Smart Contracts Alliance in collaboration with Deloitte, 2016):

- Digital identity verification: enabling a ledger-based identity record which can be automatically verified by machine-to-machine (M2M) transactions;
- The automatic release of records after a set period of time or upon application (for example, for a legal request);
- Automatic payment of securities and dividends, rather than relying on third-party custodians;
- Automated financial reporting by digital accounting systems;
- Automated transfer of ownership records (for example, upon completion of mortgage payments);
- Automated processing of insurance claims by IoT-enabled vehicles;
- Automated collection and reporting of data during clinical trials;
- Royalty distribution for use of intellectual property.

The use of smart contracts, however, may face specific challenges. Fawcett et al (2016) identify three major challenges:

Validity of data used to determine compliance: For more complex applications, smart contracts may need to review incoming data in order to determine whether conditions have been met. For example, for one prominent mooted use case of an automated futures contract in which the price of an agricultural commodity depends on the weather that year (and consequently on the yield), the software would be reliant upon a reputable source of weather data,[39] which itself may need to be

[37] As Fawcett et al (2018) note, this is a misnomer in that smart contracts are neither smart (in the sense that they are adaptive) nor contracts (in a legal sense).

[38] Complete transactions are contracts with no uncertainty in judgement as to completion or costs to write and enforce (Hart (1989), in Davidson et al (2018)).

[39] For more advanced applications, this may in future also require more advanced natural language processing (NLP) skills (Smart Contracts Alliance in collaboration with Deloitte, 2016).

verified by multiple nodes in the network. In such examples, the potential for a fully decentralised process chain may be diminished.

Need for error-free and transparent code: The reliance on code rather than legal agreement means that the risk of error or bugs in software code may leave users vulnerable to error or purposeful manipulation of the code (as in the case of the DAO described in Box 9). On a related note, parties in a smart contract transaction may need to have a sufficient understanding of the code in order to understand the terms and whether hidden terms have been included in the underlying code which are not explicitly disclosed (EY, 2017). In such cases, the unclear legal status of such contracts may mean that parties have limited or no redress in case of disputes.

Governance and maintenance of the ledger: An advanced smart contract ecosystem will need to rely upon the operation of a shared ledger (or multiple, interoperable ledgers). The maintenance, governance and operational costs of such ledgers will need to be met by the network participants.[40]

3.1.3 Business organisation

In addition to changes in corporate structures, blockchain may herald changes to organisation within service providers themselves. As discussed above, blockchain may automate or significantly alter the operation of backroom processes, through such applications as smart contracts and the automation of trust and verification mechanisms performed by third-party organisations.

Blockchain may enable new means of data management within a business, in addition to between organisations. For example, certain employees may be given permission to access different datasets using unique identification keys, with the ledger also acting as a clear and immutable record of data access, thus providing a 'trusted' record of data.

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. For example, the need for all nodes to 'agree' on the correct version of the ledger could help to identify any illicit changes which have been made to the data (for example, in the case of a cyberattack) (GOST, 2016). However, the use of shared platforms could also present a risk in its own right, as errors and bugs (for example, incorrect data added to the blockchain or an error in the code for a smart contract) could affect a larger number of operators (ESMA, 2017).

The ability to store and exchange value (or tokenised assets) on a blockchain and enable rapid cross-border exchange may also have benefits for organisations' financial management. For example, companies may choose to develop internal currencies which can be used to transfer assets between different company branches or even within their supply chain without the need to rely on external reconciliation or being subject to fees and tax consequences. Internal currencies can also be used to facilitate better record keeping of spending by employees and branches to support such tasks as filing of expense claims or analysis of tax liability (PwC, n.d.).

3.1.4 Productivity

The majority of literature reviewed for this report did not draw in great detail upon the potential productivity benefits of blockchain as a specific software solution, other than to note in general terms the benefits for productivity of blockchain's potential (PwC, n.d.; Deloitte, 2016).[41]

[40] Although the authors do not mention this, platforms such as Ethereum may offer a means for organisations to develop smart contracts without the need to develop a distinct infrastructure.

[41] One exception is Davidson et al (2018), who discuss three competing lenses for analysis of blockchain's productivity effects: blockchain as a *general purpose technology*; blockchain as an *exchange technology*, improving the efficiency and scope of markets by lowering transactions costs; and blockchain as an *institutional technology*, enabling an economy that is

At organisation level,[42] the productivity benefits of blockchain (as a digital technology) are likely to be indirect, drawing on the benefits of wider digitalisation (including benefits such as increased operational transparency, reduced transaction costs, and increased security enabled by distributed system architectures). In recording the extent to which different sectors engage with aspects of digital activity (digital spending, digital assets, digital transactions, digital business processes, digital spend per worker, digital capital deepening[43] and share of sector jobs that are digital), a report by McKinsey (Bughin et al, 2016) noted that the top five sectors were knowledge-intensive service professions (ICT, media, finance and insurance, professional services, wholesale trade). These 'highly digitised' sectors therefore stand to benefit from increases in the efficiency of these digital activities.[44]

As the report notes, key drivers of productivity at organisation level as a result of increasing digitalisation may include:

- **Labour productivity:** the benefits in efficiency by employees working with digital assets and the better matching of workers to relevant jobs through digital platforms;
- **Capital productivity:** increased asset utilisation and efficiency, and reduced downtime;
- **Multifactor productivity:** the associated benefits of labour and capital productivity improvements, including digitally enabled and more efficient research and development (R&D), leading to new and more efficiently developed products; greater knowledge generation as a result of data analytics; optimisation of operations and supply chains, for example, by the monitoring of production lines and improved logistics; and greater resource efficiency.

As discussed above, blockchain has been proposed as a potential way to increase efficiency in these areas. For example, with regard to labour productivity, blockchain could help to augment workers' activity (for example, by enabling better data analytics), thus increasing output per worker. Meanwhile, it has been suggested that the use of blockchain for human resource management, including sourcing job candidates and recording skills development, could improve overall matching of workers with jobs for their skill set (PwC, n.d.).

Capital productivity - the efficient use of capital assets, including software - may also benefit from the various features of blockchain, including greater resilience of systems (GOST, 2016), leading to reduced downtime; increased security in the face of cyber threats; and the ability to enable 24-hour operations (for example, with stock trading; ESMA, 2017).

With regard to multifactor productivity, the numerous and varied applications of blockchain mean that the benefits may be the most acute, but also the most difficult, to predict. For example, blockchain could enable more advanced uses of the Internet of Things (Tapscott and Tapscott, 2016; Nascimento et al, 2018), which, McKinsey estimates, could result in a GDP boost for Europe of between €190 billion (USD 210 billion) and €310 billion by 2025 (Bughin et al, 2016). Enhanced information sharing and storage enabled by blockchain could result in wider benefits of data analytics (see, for example, Hyperledger n.d.b) and increased trust in supply chains, thus requiring less direct monitoring (Provenance, 2015). Blockchain-based systems could also enable better energy use, thus decreasing resource waste (see, for example, Nascimento et al, 2016). However, the energy consumption needs of

'institutionally more varied and complex than an economy without' blockchain, including enabling new forms of economic activity (Davidson et al, 2018).

[42] This working paper discusses here productivity benefits at firm level; however, the link between productivity at firm level and national productivity statistics (including GDP) is not a clear relationship. See Bughin et al (2016) for discussion on this point.

[43] ICT and software assets per worker.

[44] Certain other service sectors were considered 'highly localised and fragmented' and included sectors such as hospitality and entertainment and recreation.

blockchain itself, which to date has been considered a key challenge (Deshpande et al, 2017), should also be considered in any calculation of potential benefits to resource efficiency. The extent to which investment in ICT results in high productivity also highly depends on the organisational processes and strategy and the way in which they align with the market; in the case of blockchain, as discussed above, these may be relatively complex changes in light of new models of collaboration and the overhauling of existing backroom processes.

3.1.5 New service products

The ability for blockchain to facilitate the development of new applications may also enable new outputs and products for the service sector, including both direct outputs (that is, blockchain-based apps, smart contracts) and as a foundational technology to enable further development in other areas, such as advanced Internet of Things applications. Perhaps the most prominent example of a new product resulting directly from blockchain technology are cryptocurrencies, which, in addition to enabling new functions, have themselves become assets, with new organisations (such as cryptocurrency exchanges) emerging to take advantage of new trading activity. A mapping study for the global cryptocurrency landscape in 2017 estimated that around 2,000 people were working full-time in the global cryptocurrency industry, of which the majority were working for cryptocurrency exchanges (Hileman and Rauchs, 2017b).

However, as discussed above, in enabling the automation of functions, blockchain may also render some service products (notably those provided as transaction intermediary services) defunct. For example, Grech and Camilleri (2017) note that educational organisations often make a premium on the verification of educational certificates, meaning that the activities described above may also result in a loss of revenue streams.

3.2 Implications for work and employment

Box 8. Summary of implications for work and employment

- Potential effects on collaborative work arrangements of freelancers or in the platform economy.
- There is currently limited analysis of the potential implications of blockchain on job creation/destruction, although new roles are likely to arise relating to the design, maintenance and operation of the technology, and new services are likely to arise relating to the applications enabled by blockchain.
- There is currently limited analysis of the potential implications of blockchain on work organisation and workers' experience.

3.2.1 Business models

As discussed above, one driver behind the interest in blockchain is its ability to enable new business models and forms of organisation. Tapscott and Tapscott (2016) discuss seven new 'networked business models' which could be enabled by blockchain:

1. **Peer production communities**, in which large numbers of individuals can contribute to the creation of a product (such as software development) and be rewarded for their input without the need for a single coordinating organisation;
2. Platforms to enable better **intellectual property tracking** for creators, enabling the trading of digital creative works and tracking the ownership and provenance of off-chain assets;
3. **Collaborative economy 'cooperatives'**, enabling peer-to-peer trading of services and goods (such as rental platforms which connect individuals wishing to rent their assets to another on a temporary basis);

4. **'Metering economy'** business models, in which individuals can sell and trade spare capacity (such as Wi-Fi, home-generated energy or computing power) without the need to contract with a coordination organisation;
5. The development of **enterprise platforms** upon which individuals (including separate organisations and customers) can create new applications and customise experiences;
6. **New models of manufacturing** linked to the blockchain by disaggregating production among multiple individuals (and further enabled by 3D printing);
7. **Models of collaboration between enterprises** by providing mechanisms for collaboration between and within firms (also discussed in chapter 3.1.1).

In this regard, Davidson et al (2018) characterise blockchain as being able to develop new forms of economic activity which 'were previously not able to be governed by firms, markets or governments because the transaction costs were too high to justify the expected benefits'.

The distributed, decentralised nature of blockchain and the ability to initiate micropayments and smart contracts may change the landscape for freelance workers and the platform economy, particularly when enabled by infrastructure which reduces the cost of hiring and validating potential freelancers (for example, by reducing the costs of verifying qualifications) (PwC, n.d.). The ability to make micropayments may be of particular interest to artists and creators who rely on payment for the use of their intellectual property, because these micropayments avoid the need to contract through an agency responsible for collecting royalties (Tapscott and Tapscott, 2016).

Box 9. Two DAOs

One prominent, operational DAO is the Dash Treasury DAO (often referred to simply as the 'Dash DAO'), which governs the functioning of the Dash cryptocurrency. The cryptocurrency operation is overseen by a paid core management team (Dash Central, 2015), while the DAO itself is comprised of holders of significant amounts of the Dash cryptocurrency, who can vote on proposals as to how to spend the shared treasury funds (Valenzuela, 2017). Recent votes have included proposals to sponsor external events, to develop promotional material for the cryptocurrency, to institute compensation for the core operation team, and issues related to the functioning of the cryptocurrency system (Dash Central n.d.b).

On the other hand, in understanding the potential challenges posed by the operation of DAOs, it is instructive to consider the example of one of the early DAOs, established on the Ethereum platform (confusingly also often referred to simply as 'the DAO'; hereafter, we use 'the Ethereum DAO'), in which the theft of USD 70 (€ 62) million from the collective - an operational failure - led to a disagreement over the appropriate response, thereby presenting a governance issue.

The Ethereum DAO was originally established as an investment vehicle, with all 'shareholders' assigned voting rights based on their financial contribution. However, an unknown user was able to exploit a loophole in the code to instruct the blockchain to repeatedly transfer Ether (the currency token associated with the platform) into a single account, at the time worth USD 70 (€ 62) million.

In the absence of a hierarchical decision-making structure, the community was split between those who felt that the smart contract code - the 'rules' - should be considered sacrosanct, and those who argued that the community, using the power of the majority, should force a change to the blockchain to reverse the transaction. Ultimately, the 'hard fork' to reverse the transaction was initiated, but it split the community, with some users opting to continue to use the original blockchain ('Ethereum Classic').

Source: Dunn, 2016; Siegel, 2016; and Rizzo, 2016.

Blockchain may also facilitate the development of cooperative models of organisational governance by providing a framework for decentralised decision making and the dispersal of assets among partners (for example, profits being distributed automatically as cryptocurrency to cooperative partners) (Tapscott and Tapscott, 2016; Davidson et al, 2018). One example of this is the potential creation of a decentralised autonomous organisations (DAO) or the decentralised autonomous corporation (DAC). These are models of organisation in which decisions are made by votes of members using their unique tokens (not dissimilar to traditional cooperative business models) - thus removing the need for many standard corporate architecture and governance procedures, as decisions would be made entirely (and autonomously) on the basis of electronic 'votes' by members. Wider issues relating to accountability, liability and responsibility for maintenance may be challenges for both decentralised organisations themselves and regulatory bodies, and organisations themselves will face the challenge of establishing clear governance mechanisms.

Nascimento et al (2018) hypothesise that the ultimate consequence of the trend towards open-source development, IoT applications and the benefits of data pooling may mean that some work sectors move towards a more open model of business, in which open, data-rich ecosystems are the norm within or between sectors and specific applications are built (and monetised) by organisations on top of this shared base. This may further encourage micro entrepreneurship for commercial and social purposes, as even small developers can access the data required to create some data-reliant applications, and enable the development of a 'data economy' based around individuals and organisations sharing and trading their data. However, the development of large-scale, radical, decentralised applications may also depend on cultural and economic factors, such as the extent to which individuals are incentivised to self-organise to adequately develop and maintain such platforms, and the attaining of a critical mass of users to achieve positive network effects.

In this regard, a shift brought about by blockchain may be the change in perception of what it means to *be* a business, an employer and an employee, as companies reduce physical, well-defined infrastructure and management structures (Manski, 2017); applications run at peer-to-peer level; and the traditional perception of the hierarchical firm as the most efficient form of organisation is undermined (Hanson et al, 2017). While the extent and speed of these conceptual and cultural shifts is harder to predict with any certainty, the implications over the longer term may be just as acute.

3.2.2 Employment and skills

The loss of jobs as a result of the wider automation of processes has been cited elsewhere as a potential implication of the adoption of digital technologies, notably as a result of advances in Artificial Intelligence and advanced robotics (see, for example, Frey and Osborne, 2013). While this has been cited as a risk by some commentators (for example, Manski, 2017), the study team found very limited evidence in the literature on the potential implication of blockchain on job loss or gain. Discussion of wider task automation has often highlighted the potential polarisation of the labour market as a result of the automation of middle-skill jobs in particular (EU Skills Panorama, 2015), although the precise risk of automation is likely to differ significantly across sectors and different job roles. 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.

> *Because [the sectors] have complex ecosystems… Managing all of that, even in consortium through a blockchain, is going to improve a lot. So a lot of the operators which were in between managing paper contracts, etc., and some of the business processes which were suboptimal… blockchain would organise all of that process. …some intermediaries, if they don't review completely the way they work, they are going to disappear. So in terms of a game changer and Darwinian evolution of the*

> *market, where you will have winners and losers, I think it will be huge.* (European public sector expert interviewed for this project)

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. Blockchain engineers and software developers are already in demand, while service organisations focusing on technical blockchain development, consultancy and services are emerging, in addition to wider legal and regulatory consulting (Hileman and Rauchs, 2017a). New job roles, such as blockchain data analytics specialists, may be created (for example, firms specialising in 'forensic blockchain analytics' to support investigations are already operational) (Hanson et al, 2017; Hileman and Rauchs, 2017a). Given the complex nature of the technology, it seems likely that many of the jobs created will be in high-skill professions, such as programmers, developers, IT consultants and cybersecurity professionals (Maupin, 2017), although a range of associated support roles, such as custodians of off-chain assets, may also arise (Hileman and Rauchs, 2017a). In a recent survey of business leaders, the vast majority of respondents in France (84%), Germany (61%) and the UK (76%) (the only EU nations polled) stated that they were investing in hiring staff with blockchain experience or intended to do so within the next calendar year (Deloitte, 2018a).

According to aninterview with an European public sector expert, the increasing adoption of blockchain technology and applications may also change the content and skills required by some job roles, both by adding to the broader need for digital skills and by requiring specialist skills relating to the applications of blockchain technology. For example, law firms engaged in issues relating to smart contracts may require greater in-house technical expertise to understand and analyse the legitimacy of the underlying code (Iansiti and Lakhani, 2017), while regulatory bodies will need to understand how the nature of blockchain-based activity in their sector fits into the larger regulatory picture (Hileman and Rauchs, 2017a). Intermediary organisations at risk of disruption or automation may also choose to pre-empt this outcome by adopting blockchain themselves to offer to their existing clients. For example, the banks of the future may need fewer accountants and more programmers. At the same time, software developers may need in-depth knowledge of the sector for which they are designing the blockchain, in order to effectively build in consideration of the regulatory or legal requirements of the sector (Hanson et al, 2017).

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). 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. One interviewed European third sector expert also noted that, rather than developing a general knowledge of a field, blockchain would drive further specialisation among individuals in the labour market:

> *In the service sector, you need very narrow specialisation, so this is the future. No more general knowledge about patent law – now you need expertise a little bit from IT, a little bit from law, a little bit from finance… this is not just true for lawyers, but also IT developers, as you have special programming languages which are only relevant for blockchain. So I would say that blockchain and other technologies will have an impact on the labour market, on our school system, in a way that new circumstances on the labour market demand specialisation.*(as per the same interviewee)

The adoption of blockchain technology may have wider macroeconomic implications for the service sector landscape and number of jobs as a result of the increasing economic interconnectedness brought about by digital platforms and cryptocurrencies, including wider economic growth as a result of new service products and efficiencies, and potential vulnerability in the financial system (Stewart et al, 2017). Notably, any widespread adoption of cryptocurrencies, enabled by blockchain, may have particular consequences for the ability for governments to track both licit and illicit money flows for tax collection and crime prevention (Maupin, 2017) and to analyse the value of organisations' cyber-assets, which are not based in any particular geography.

On a related note, the availability of cryptocurrencies for use as payment may also reduce transnational barriers to remote working and remittances; for example, services are now available to automatically transfer salaries into the currency of another country by using a cryptocurrency as an exchange currency, thus avoiding the higher costs for foreign exchange services (Reuters, 2018).

As with the wider trend towards the digitalisation of services, the transnational nature of blockchain may also require rethinking of how to collect data and calculate economic statistics (López González and Jouanjean, 2017), particularly if, as in the case of cryptocurrencies, company assets (such as data or tokens) have no physical equivalent.

3.2.3 Working conditions

While the literature discusses various potential implications of blockchain adoption for business models and forms of sector collaboration, the implications for the experience of employees in such areas as working conditions is, however, uncertain, and these implications did not feature prominently in the literature reviewed.

It seems likely that new models of business collaboration will develop alongside existing, hierarchical business models. While shifting models of business organisation and sector collaboration may serve to eventually undermine the market dominance of established companies (Nascimento et al, 2018), this is unlikely to be the case to any great extent in the short-term future. Similarly the working experience of employees in the service sector may not see changes in the short-term over the introduction of blockchain-based solutions into their roles.

However, as discussed above, the literature reviewed often cites blockchain platforms as an enabler of the further development of the platform economy[45] and other forms of decentralised and freelance working (see chapter 3.1.1). One interviewed European public sector expert also considered that the increase in distributed work and teleworking facilitated by blockchain would further challenge traditional models of country-based unions. As has been noted more widely in the case of the platform economy, any increasing dispersal of workers due to decentralised business models or freelancing may make it more difficult for workers to organise, thus decreasing the bargaining power of employees relative to their organisations (Johnston and Land-Kazlauskas, 2018). While another interviewed third sector expert did not see a current link between blockchain and any specific implications for collective employment relations, they did acknowledge that the developing platform economy (which could potentially be enabled by blockchain) could have an impact on employer-employee relations.

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 labour rights in response to developments such as these and the more transformative applications of blockchain discussed in this paper (such as new, decentralised business models).

[45] The term 'platform economy' is used to describe the activity of digital networks that coordinate transactions, both commercial (such as the provision of goods and services for payment) and non-commercial (such as volunteering activities or social media). The platform economy offers an emerging form of employment which involves 'the matching of supply and demand for paid labour through an online platform'. See Eurofound (2018c) for more details.

3.2.4 New financing models for business

The ability to launch blockchain tokens has also enabled the creation of new financing models for start-ups in the form of initial coin offerings (ICOs). In ICOs, early investors are rewarded with currency tokens (instead of traditional shares), which, in the majority of ICO models, can be used as payment for future services by the start-up (not dissimilar to some crowdfunding models) or as a share in future profits. For example, a music streaming service may offer early investors tokens that can be later 'cashed in' for a set amount of music streaming, thus providing a new model of raising investment finance via a self-executing contract, and in doing so also bypass traditional jurisdictional, geographical or regulatory barriers. This could also enable a secondary market in tokens, acting as a new class of online currency.

Box 10. Types of tokens

Blockchain can support the creation of tokens to signify and trade ownership of an asset. Different types of blockchain-based tokens will be employed by organisations for different purposes. While the lines between types of token are blurred, three broad types of tokens can be identified:

- **Cryptocurrencies:** Bitcoin and other blockchain-based currencies ('altcoins') which are created for the purpose of functioning as money;
- **Asset-backed tokens:** Tokens which represent an asset held off-chain (for example, a land title);
- **Network tokens:** Tokens which are related to their specific platform or application (such as Ether, which is used to 'pay' nodes to enable functions such as data storage on the Ethereum blockchain) or which function as part of a smart contract (for example, 'token as a share').

Tokens may be integrated at any layer of the blockchain.

Source: Adapted from Euler (2018).

Analysis of the ICO market found that, as of November 2017, cumulative proceeds from ICOs were almost USD 4 (€ 3.54) billion in value, compared to an estimated USD 1.9 (€ 1.67) billion venture capital in the blockchain sector, with ICO projects predominantly originating in the USA, Russia and East Asia (Ernst & Young, 2017).

Box 11. Blockchain and the risks to security and privacy

The distributed nature of blockchain technology combined with its capability to store data cryptographically as an append-only log of timestamped records is designed to make it more resilient to tampering (Henry et al, 2018). However, the decentralised approach to governance and inherent anonymity available to users also pose challenges when the adoption of blockchain in business environments is considered (Meiklejohn, 2018). Although the users' identities are pseudonymised, the details of the transactions are completely transparent and thus the extent to which blockchain can provide privacy (as opposed to anonymity) to its users has been questioned (Bonneau et al, 2015). Ethereum, one of the most prominent blockchain-based platforms has suffered multiple cyber-attacks which have resulted in significant loss of value for the users of the platform (Atzei et al, 2017). Although the distributed nature of the technology and decentralised administration of its data nodes makes the technology resilient to complete data loss, it remains susceptible to security and privacy failures. Ongoing research suggests that achieving effective privacy in general distributed ledgers such a blockchain remains an open question (Meiklejohn, 2018). In the absence of widespread commercial use and lack of legal frameworks to monitor and adjudicate on smart contracts, there are, as yet, limited precedents on the use of blockchain in a workplace and any impacts on security and privacy of the workers.

In this context, the EU's GDPR and its legal framework and protection for personal data could prove crucial since it makes collecting and processing these data without explicit user consent unlawful. However, Jülicher and Delisle (2018) argue that even those users who take it upon themselves to read multipage privacy policies have difficulties in assessing what actually happens to their data. As Atzei et al (2017) highlight, such a situation is exacerbated by the inherent anonymity and cryptographic protections of blockchain which makes it harder to determine and recover loss of data as the cyber-attacks on Ethererum have demonstrated. With GDPR, in the context of a workplace, such risks are likely to be mitigated for employees when the employer has mandated the use of blockchain. Some of the transpositions of the EU GDPR into Member States' national law explicitly recognise workers' rights to privacy when using their employers' digital tools including technologies such as blockchain. The Organic Law on Data Protection and Digital Rights Guarantee (LOPDGDD) enacted by the Spanish parliament in 2018 is an example of this kind of legislation (Jefatura del Estado, 2018).

Source: Atzei et al, 2017; Bonneau et al, 2015; Henry et al, 2018; Jefatura del Estado, 2018; Jülicher and Delisle, 2018; Meiklejohn, 2018

4. Conclusions

This study aimed to understand the implications of blockchain as a potential game-changing technology area to the services sector in Europe. Blockchain offers great promise to radically reshape the way information and value between individuals and organisations is transferred. However, the technology is still very new and evolving; as a common refrain goes, it has ‘not yet had its browser moment’ (Impactt, 2018), referencing the way in which the development of the internet browser enabled the move from the internet as the preserve of enthusiasts and those with the technical expertise to something with which the wider public could engage with - a move accompanied by a subsequent explosion in the use and the development of digital platforms in new and unexpected ways. Although the specific outcomes related to jobs, required skills, working conditions and workplace practices in the services sector are still emerging - and vary significantly depending on the needs of the different sectors - early adoption trends and high-level implications of blockchain can be discerned. This section summarises the key findings in relation to the primary objectives and the main elements of the conceptual framework outlined in chapter 1.

4.1 Applicability of blockchain in the services sector

Blockchain-based applications are starting to reach the market, with interest from both start-ups and established companies. Much of the developments in the blockchain ecosystem have occurred as a result of the efforts of open communities and non-profit initiatives. Furthermore, there has been strong interest in blockchain from governments in the context of potentially applying blockchain-based solutions to deliver government services, but also more broadly, to help develop the technology to facilitate economic advantages. Specifically, the financial sector has shown a great deal of interest, but several use cases have also been proposed for the logistics/supply chain, health, education, media, and public service sectors. Nevertheless, many of the applications which we currently see reaching the market are, as predicted by Iansiti and Lakhani (2017), single-use and low-novelty blockchain applications. In practice, some of these simply replicate the activity of existing, centralised institutions through a decentralised platform, but often while retaining control by a single organisation or consortium. These applications may offer marginal benefits to security, transparency and process over existing solutions. However, there are also a fewer applications which aim to fundamentally reshape the way activities have been performed so far.

4.2 Potential implications of blockchain on productivity, output, and work organisation

In relation to productivity and output, blockchain platforms may facilitate new or alternative methods of collaboration between service sector organisations (based on a shared data layer); this has implications for the role and nature of providers of intermediary services. Blockchain may also enable the development of new service products and outputs - including direct outputs (such as cryptocurrencies, smart contracts and blockchain-based apps) as well as providing the underpinning technology that could enable development in other areas (such as advanced Internet of Things-based applications). Through the use of smart contracts (and internal/sector currency tokens), blockchain could enable the automation or streamlining of business processes, with potential implications for productivity and internal organisation. Initial coin offerings could serve as a new means of crowdfunding and potentially attracting investment for organisations.

However, it is worth bearing in mind that there are still some functions of hierarchies that may be preferable for consumers, such as quality assurance, and accountability and reimbursement in the case of faulty/insufficient services. While in the longer term we may see new models emerging to account for this - such as individuals purchasing insurance for faulty services in a P2P transaction, rather relying on recompense from a hierarchical body which is formally accountable for the service - blockchain may not be the optimal solution in the short term for many use cases.

4.3 Potential implications of blockchain on employment and skill levels

The early socioeconomic implications of blockchain for individual workers are likely to be akin to those of the wider digitalisation trend, with the associated need for increased STEM skills and wider changes to business models (such as the platform economy). One interviewed European public sector expert considered that trends in the digitalisation of the economy would be accelerated by blockchain. However, over a 3-5 year time period, while the 'blockchain economy' may itself grow, with new jobs and businesses created, it is unlikely that blockchain will have a significant impact on the daily working experience of individuals in mainstream occupations. It has been noted that the distributed nature of the technology and its ability to execute micropayments and smart contracts could change the landscape for freelance workers and the platform economy, as well as enable the development of alternative, cooperative models of organisational governance. Finally, as the technology 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, the labour market implications of blockchain cannot be predicted with any great specificity.

4.4 Potential implications of blockchain on working conditions

As individual users often interact with blockchain applications through straightforward user interfaces, the experience of workers in engaging with blockchain in the workplace over the short-term future is likely to be akin to that of adopting other new forms of software.[46] Ultimately, the implications of blockchain technology as a transformative technology for working conditions will greatly depend on the actions taken by governments with respect to such elements as labour rights and social security, in light of new business models and employment trends enabled by the technology.

[46] For example, a recent report on the creative economies featured some examples of sector players who felt that blockchain was not suitable for their models, and concluded that 'there are not enough current use cases to be confident in the ability of the technology to dramatically change the creative economy for the better' (World Economic Forum, 2018a).

5 Real-world case examples illustrating the applicability and potential implications of blockchain

Below, three examples of 'real world' applications of blockchain in the services sector are described. The examples are intended to illustrate rather than assess the applicability and implications of blockchain applications in the services sector. Instead of offering insights on a broad range of impacts for blockchain (as has been presented in chapter 3), the case examples are meant to succinctly exemplify potential or realised implications in one or two (or more, where information is available) areas. The examples are meant to enrich the overarching analysis presented in this working paper by offering a real-life illustration of how these applications have had or will have implications in practice.

Table 6: Case example 1: Nasdaq eVoting initiative

Nasdaq eVoting initiative
Location: Tallinn, Estonia (pilot); as of 2017, offered worldwide
Example service sector(s) the case example applies to: • Financial and insurance activities (NACE sector K); • Professional, scientific and technical activities (NACE sector M); • Administrative and support service activities (NACE sector N).
Background and overview of the technology: Nasdaq is a global financial services firm which provides a range of services for the financial sector, including trading, clearing, exchange technology, listing, information and public company services. As part of this, it develops and offers technological solutions for market infrastructure organisations and participants, including broker-dealers, exchanges, clearinghouses, central securities depositories and regulators, in multiple countries. As part of its general technology and research and development strategy, Nasdaq business units have been piloting a number of blockchain-based technologies. This includes Linq, a pilot platform to allow private securities transactions between private customers, with the aim of reducing inefficient management, including reliance on paper-based certificates; the development of a prototype for the issuance and settlement of mutual fund shares; and a blockchain-based eVoting solution to enable shareholder voting, which is the subject of the current case example (Nasdaq, 2018). Current shareholder voting processes are often conducted in person at annual general meetings (AGMs), or through other, non-blockchain-based e-voting solutions, according to an interviewed Nasdaq representative. Voters may transfer their vote to a proxy to vote on their behalf by private arrangement, although various paper-based processes are required ahead of the AGM in order to verify the right for the proxy to cast a binding vote. In this regard, the stated aim of the solution is to streamline voting processes, particularly with regard to reducing the complexity of proxy management and improving the transparency of voting and results during company voting events (Nasdaq, 2018). As of 2017, the e-voting solution is offered to central securities deposits (CSDs) globally, including a project to integrate the technology for its first customer, South African CSD Strate (Nasdaq, 2017a). According to the interviewed Nasdaq representative, the technology was created following a 2016 pilot at the Nasdaq Tallinn exchange, involving 5-10 companies. Estonia was selected as a pilot site in part due to its e-residency initiative, by which any individual or company can receive a government-verified digital signature for use in online transactions. As the CSD was owned by Nasdaq, the company already had existing relationships with key parties and owned the data about ownership of shares that would enable the pilot (Nasdaq 2017b). The blockchain is based on technology developed by Chain, an enterprise blockchain provider that develops blockchain tools for the financial sector (Nasdaq, 2017b). As the interviewed Nasdaq representative noted, the use of a blockchain to store data means that the ownership of assets, transactions and account details can only be viewed by those with the correct set of identification keys. In the system, organisations can create asset wallets and issue voting rights to individual users. The users can then vote or assign those votes to another user, and monitor the way that those votes are cast by the proxy by reviewing the information stored on the ledger. Customers access a web-based, front-end system, which the interviewee considered no

more complex than other e-voting solutions currently available on the market. The interviewed representative did not consider scalability an issue for a solution such as this, as the throughput (the number of users voting at any one time) would not be significant. For holders of securities, the e-voting platform would mean that they could review a transparent voting history, including monitoring a chain of proxies (Nasdaq, 2017a). For the organisation itself, the use of an e-voting platform could help companies to engage more retail investors (such as individuals who may not have the capacity to send representatives to AGMs); tally results instantly and reduce voting complexity, as note by the interviewed Nasdaq representative; and provide an end-to-end solution to allow companies to organise meetings, distribute materials and tally votes within the same application (Nasdaq, 2017a). While these benefits are available on standard e-voting solutions, the interviewed Nasdaq representative considered the transparency and immutability benefits offered by blockchain to be of value, particularly with regard to transparency between the principal and proxy voter by using smart contracts to transfer voting rights in place of paper-based processes. The level of transparency in the blockchain (for example, who has privileges to view the ownership and voting information) and the method by which the nodes reach consensus will depend on the particular implementation case, according to the interviewed Nasdaq representative. For certain customers, this may in the future include providing access to ownership and transaction records to auditors or regulatory authorities in order to comply with oversight laws. As shareholder voting processes are subject to different regulatory requirements in different jurisdictions, the user authentication process would be tailored for different countries. In this regard, the same interviewee considered that the EU provides a level of harmonisation across laws and regulations in the European market which is of benefit to Nasdaq as a technology vendor. While the solution is being marketed only in the financial services sector as of 2018, the interviewed Nasdaq representative suggested that a move into other sectors which make use of e-voting could be considered in the future.
Illustrations of potential socioeconomic implications: As a new form of e-voting solution, many of the implications of introducing a blockchain-based system may mirror those of standard (that is, non-blockchain) e-voting solutions. According to an interview with the Nasdaq representative, the use of e-voting solutions in general could streamline processing for companies and reduce the time needed for companies to manage the voting process, providing real-time voting results, and it could enable one-stop and frequent engagement with shareholders (for example, by providing documentation at the point of e-voting). Similarly, the same interviewee did not consider that the experience for front-end users (individuals or organisations with voting rights) would differ significantly from other e-voting solutions on the market, with their existing benefits (for example, the convenience of online voting rather than in-person attendance at an event). In this regard, the same interviewee noted that the main implication of using a blockchain design over existing software would be that participants ‘could sleep better at night’ due to the security and immutability benefits of blockchain, by being able to track votes and reassure parties in case of disputes. The interviewed Nasdaq representative suggested that the implications for companies themselves (including the efficiency and productivity savings) would depend on the extent to which they employed manual processes or e-voting to conduct existing voting processes. The same interviewee did not consider that there would be clear productivity benefits from blockchain e-voting solutions outright in the short term at least: while blockchain may be easier to work with, it would also require people to understand the working of the system, which remains a challenge to adoption. The interviewed Nasdaq representative did not consider there to be any implications for

technical skills on behalf of the company implementing the blockchain-based system for their shareholders beyond those needed to engage with existing digital e-voting solutions, as the users engage with the blockchain solution through a standard user interface. Additional skills may be required on the part of the CSD, depending on how advanced the solution they offer to their customers will be - for example, whether they offer additional development for their customers (requiring the necessary technical and operations skills and employees) or simply implementation of the existing model. However, education on and understanding of how the blockchain system operates may be required in the sector more generally among legal and regulatory persons, to approve the solution for implementation, according to the same interviewee (for example, by understanding the way that the design of the blockchain system relates to existing national and international law governing shareholder rights, proxy voting and data protection, such as the EU Shareholder's Rights Directive (European Parliament, Directive 2017/82)).

However, the interviewed Nasdaq representative felt that, in the longer-term future, blockchain-based e-voting systems could have the potential to connect shareholder voting processes across jurisdictions, enabling shareholders to participate in company governance processes across the globe through a single system. Shareholders in the global market can often own shares in many different companies and across different jurisdictions, making it complicated for them to understand and participate in different voting procedures. According to the same interviewee, standardisation could enable shareholders to participate in voting procedures in multiple countries after a single identity-authentication process, whether implemented by a single operator or multiple, connected e-voting providers.

Table 7: Case example 2: University of Nicosia Academic Certificates Initiative

University of Nicosia Academic Certificates Initiative
Location: Cyprus (system offered worldwide)
Example service sector(s) the case example applies to: • Professional, scientific and technical activities (NACE sector M); • Administrative and support service activities (NACE sector N); • Education (NACE sector P).
Background and overview of the technology: The University of Nicosia (UNIC, based in Cyprus) Blockchain Initiative hosts a range of blockchain activities, including an accredited master's degree in Digital Currency (taught online) and a Massive Open Online Course (MOOC) on digital currencies and professional certificates (University of Nicosia, n.d.a). According to an interview with a UNIC representative[47], Bitcoin is accepted as a means of payment for courses, with the intention of raising awareness of the way that the technology could be utilised. As part of the initiative, academic certificates for students who have successfully completed the formal courses and MOOC are hosted on the Bitcoin blockchain in order to enable self-verification by external organisations. When a cohort of students graduates successfully from a programme, they are provided with an electronic copy of their certificate as a PDF document, which can be shared with potential employers. Simultaneously, an encrypted digital signature of the certificate is published on the Bitcoin blockchain by attaching the signature of a document to a Bitcoin transaction, which enters the standard record of Bitcoin transactions. (For a full description of the process, see Block.co (n.d.a).) Organisations which wish to verify the authenticity of the certificate can do so by examining the transaction on the blockchain to ensure that the certificate is a match, or by uploading it to an automatic verification portal on the UNIC website (University of Nicosia, n.d.b), without the need to contact administrative teams at the university directly. Another interviewed UNIC representative noted that the reason for using the Bitcoin blockchain rather than a dedicated platform was its transparent nature and the knowledge that it is robust and secure, having been well tested through the operation of Bitcoin (the Bitcoin blockchain is used by the Massachusetts Institute of Technology (MIT) Media Lab for their own system for the same reason (MIT Media Lab, 2016)). Since 2015, more than 8,000 certificates have been published by UNIC on the blockchain and other issuing authorities that use the solution. Instructions for organisations to undertake a similar process and the standard source-code allowing third parties to run their own issuance services for their own certificates are made available free of charge by the project team. According to another interviewed UNIC representative, this open-source nature aligns with principles of academic exchange and the open-source philosophy of the blockchain community. However, a spin-off company, Block.co, has been launched to provide commercial services, such as customisation of digital certificates for organisations or other special requests. In addition to the initiative by UNIC, other organisations, such as the MIT Media Lab (MIT,

[47] The study team interviewed two representatives of UNIC

n.d.) and private companies (Smart Certificate, n.d.), are developing similar blockchain-based initiatives. The MIT Media Lab has also developed the Blockcerts open standard for issuing certificates, to encourage interoperability of blockchain-based certificates across providers (Blockcerts, n.d.; Grech and Camillieri, 2017). An interviewed UNIC representative highlighted that the main driver of hosting academic certificates on a blockchain is the desire to streamline the administrative processes involved in issuing and validating certificates. Currently, in the majority of cases, organisations wishing to verify the credentials of an individual must manually contact the issuing organisation, although some non-blockchain digital solutions do allow self-verification through centralised online portals (see, for example, My eQuals (n.d.), used to store and validate digital certificates by universities in Australia and New Zealand). This implies costs in terms of human labour to validate the certificates, as noted by another interviewed UNIC representative, or financial costs to contract a separate company to store and validate digital certificates. The same interviewee suggested that the use of digital certificates that could be self-verified by organisations could help organisations to become increasingly paper-less and thereby drive efficiencies. The additional benefits of using a public or multi-party blockchain over a centralised solution would mean that even if the university (or certificate-issuing organisation) was to cease existing, previously issued certificates could still be verified as long as the blockchain endured, as noted by an interviewed UNIC representative. MIT, for example, notes that one particular example of a beneficiary group could be refugees seeking to validate their credentials to find work in their country of refuge (MIT Media Lab, 2016). The use of blockchain rather than a centralised third-party provider would also lessen the risk that individuals at the validating organisation could abuse their position and would lessen the vulnerability of the digital records to data leaks or system failure (Grech and Camilleri, 2017).
Illustrations of potential socioeconomic implications: As the issuing of digital certificates by UNIC was taking place alongside the standard certificate issuance process, the administration of the blockchain certificate system was comparable to the traditional process, involving all the traditional departments and with just an additional step for the project team to issue the blockchain version of the certificates, according to an interview with a UNIC representative. There may be different efficiency and cost saving impacts for an organisation if the digital certificates replaced the printing of hard copies of certificates entirely. However, the ability to self-certify using digital certificates would be a significant time-saving mechanism for validating certificates for issuing and validating organisations, as the certificate can be verified instantaneously in a couple of clicks, rather than in the hours or days needed to transact over manual channels, according to one interviewed UNIC representative. While these benefits may also be realisable from wider use of digital certificates, the interviewee considered that the use of blockchain made the process ‘secure and transparent’. However, the extent to which these benefits represent efficiency savings for issuing organisations also depends on the extent to which these processes are conducted in parallel to, or instead of, existing manual processes. One interviewed UNIC representative argued that the whole landscape would not change immediately, and that blockchain would replace authentication processes in their entirety, although the project team anticipates that the digital issuance and self-verification of such certificates will at some point replace traditional issuing processes, as per the two interviewed UNIC representatives. The ability to issue and self-certify certificates using a public blockchain could also reduce costs for the issuing and validating organisations or students, by avoiding the fees paid to a third-party provider (or to the issuing organisation). However, Grech and Camilleri (2017) also note that a counter to this would be if the sector began issuing certificates primarily

through closed proprietary platforms, which would demand a fee for access.

One interviewed UNIC representative assessed that there would be no significant need for particulary/additional skills on the part of administrative workers as the administration of the system is quite straightforward (the research team themselves issue the digital version on the blockchain at UNIC). The interviewees, both representing UNIC, noted that this would also be true of other organisations, with basic programming skills required to implement the core system and more advanced skills required to customise it. Administrative staff seeking to validate the certificates can also do so through a user-friendly portal on the UNIC website (UNIC, n.d.b.).

The use of similar blockchain-based certificates has also been suggested elsewhere as a means by which an organisation can potentially act as a single repository of informal and extra-curricular learning and development, which individuals can use to present their non-formal experience to prospective employers or educational institutions (PwC, n.d.; MIT Media Lab, 2016; Grech and Camilleri, 2017). For example, it has been suggested that a blockchain structure could act as a decentralised underlying infrastructure for systems akin to the ‘Open Badges’ initiative led by the Mozilla Foundation (OpenBadges, n.d.), in which different organisations could develop and award their own ‘badges’ (similar to Guide/Scout badges), which could be verified by interested parties, allowing the individual to collect, control and display these badges online as they saw fit as a record of their wider skills and experience (MIT Media Lab, 2016; BadgeChain, n.d.).

In addition to academic certificates, the same process could be used to produce certificates in other sectors, such as intellectual property, loans and grants and professional accreditation (Grech and Camilleri, 2017).

Table 8: Case example 3: Provenance supply chain tracking

Supply chain tracking
Location: UK-based; to involve multiple actors in multinational supply chains
Example service sector(s) the case example applies to: • Wholesale and retail trade; repair of motor vehicles and motorcycles (NACE sector G); • Transporting and storage (NACE sector H); • Administrative and support service activities (NACE sector N).
Background and overview of the technology: Provenance is a UK-based blockchain start-up which aims to provide a common platform for retailers and consumers to track products through the supply chain, from producer to end user. As of 2018, products which are certified to meet certain standards (such as environmental standards, or fair trade or organic products) are certified by an independent authority, and the certification is included as a graphic or label on the end product (Provenance, 2015). However, this type of certification could be vulnerable to fraud or corruption, such as the 'double spending' of certification (receiving a certification for a particular output and re-using this certification for products which do not meet the same standard) or fraudulent products. Provenance aims to reduce the potential for fraud in the supply chain by providing a 'single source of truth' for each individual item through the use of a shared blockchain, in which producers, standards and audit organisations, and end users can certify the origin, current ownership and supply chain movements of an asset. The goods can then be tracked at all stages using some form of identifier (such as a serial number, bar code, digital tag) at a 1:1 ratio, so the same amount of goods going in are coming out (Provenance, 2015). In addition to the manufacturers and end users of an asset, standards-awarding bodies and auditors could interact with the blockchain to certify that an asset meets their criteria, based on off-chain inspections and activity (for a more in-depth description of the process, see Provenance (2015) and Schaeffer (2017)). The organisation was originally funded by grants (primarily from Innovate UK, the UK public body for innovation funding), but it has since received investment funds (Allison, 2017). As part of the development of the platform, a six-month pilot was carried out in 2015 on Indonesian tuna fishing supply chains with the International Pole & Line Foundation (IPNLF), an international NGO focusing on encouraging sustainable fishing practices in tuna fisheries around the world, with, among other things, an emphasis on working conditions for fishers and increasing the social contributions of the fisheries to vulnerable coastal fishing communities, according to an interview with a IPNLF representative. IPNLF is a membership organisation, with retail and corporate members from across the EU and worldwide, including Actemsa (Spain), Calvo (Spain), Conservas Emperatriz (Spain), The EDEKA Group (Germany), Frinsa (Spain), The Migros Group (Switzerland), Pão-do-Mar (Portugal), Sainsbury's (UK) and Marks & Spencer (UK). Current practice in tracking fish across supply chains differs across markets, but primarily by passing through a variety of different organisations. Seven of the eight Indonesian processing companies visited by Provenance were using paper-based accounting (with some use of Excel), with only one company visited making use of digital technology (Provenance, 2016). The intention of the pilot was therefore to make the data interoperable across the supply chain and track the asset (the tuna fish) from the fisher to the customer. In the pilot, fishers used text messages to register a catch on the blockchain. Using the app, ownership of the fish was then transferred to the different processing outlets and suppliers along the supply chain, until it reached the UK market. As part of the pilot, Provenance also worked with a small retail outlet in the UK to conduct a workshop to explore the use of tags and stickers in-store which customers could scan to view information on the

blockchain (Provenance, 2016). The outcome was the decision to focus on in-store tablets and customers' own smartphones to scan product stickers that would display the product information, rather than relying on the traditional printed material.

According to the interviewed IPNLF representative, the driver behind the pilot on the part of IPNLF was the desire to trial innovations with the intention of supporting positive social impacts for small-scale fishers and fishing communities gained through improved market traceability, rather than simply the environmental/sustainability aspects prioritised in other certification schemes.

The interviewed IPNLF representative noted that for retail organisations, drivers include the need to meet consumer demands and expectations relating to positive supply chain and ethical standards, and to meet regulatory obligations, such as the European Commission Regulation 1005/2008, which mandates 'catch certificate' for any wild seafood imported into the EU to ensure that the fish were caught in compliance with sustainability standards. According to the same interviewee, large retail organisations may also face significant reputational risks if fraudulent or illegal activities are exposed in their supply chain, thus driving a need for transparency along the chain. In spite of the pilot, the same interviewee noted that blockchain solutions were not currently their priority as the organisation were focusing on other innovations, but that they may look at blockchain again in the future.

Illustrations of potential socioeconomic implications: The interviewed IPNLF representative noted that the system could potentially be used in the future to increase transparency around workers' rights and wages in a supply chain. This could be by generally encouraging greater transparency by allowing consumers to understand the provenance of their purchases or, potentially, by allowing workers to self-certify their working conditions (including information such as the time, day, and location where the fish was caught) directly onto the shared blockchain (Provenance, 2016). In a separate pilot focusing on supply chains for farmers in Indonesia, Provenance used their technology to allow end users to scan a QR code to verify that Indonesian farmers who had harvested the coconuts had received a living wage (based on a fee-per-coconut) for the good (Fairfood, 2017). The farmers were able to confirm on the blockchain via text message that the promised price had been paid.

The extent to which the use of blockchain would affect day-to-day administration of a supply chain would depend on the individual organisations participating in the supply chain and on the extent to which they currently employ digital or paper-based processes. The interviewed IPNLF representative considered that the same level of data capture would take place with a blockchain system as with other digital platforms, but that digital platforms would be more efficient than paper-based systems. According to the same interviewee, organisations throughout the supply chain could potentially benefit from a more streamlined system to reduce the costs of data input and management, including fewer employees being required to input data.

The interviewed IPNLF representative considered that there would not be a large impact on skills needed to interact with the blockchain system by those certifying goods along the supply chain, as many of those involved with processing goods (such as fishers) could do so through a mobile phone. Other skills and infrastructure requirements for organisations along the supply chain could depend on the way that tracking was implemented, for example, the use of material tags (requiring manual data entry) compared to RFID tags (requiring a means of digitally scanning the asset tag). The same interviewee also noted that there had been some challenges around understanding the new technology, as retail partners had difficulty in understanding the intricacies of the system.

In the longer term, more transparency in the supply chain (and the consequent reduction in uncertainty and risk among suppliers) could have wider implications for sector financing. For producers of goods, the interviewed IPNLF representative considered that the increased traceability and transparency benefits offered by innovative digital solutions could also enable greater access to the financial system. In the longer term, Provenance suggests that payments between suppliers could be integrated through the use of stable cryptocurrencies (Impactt, 2018). They also suggest that supply chain data could be used as evidence of sustainable practices, encouraging lower rates for supply chain finance.

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Annex – Further details about the research approach

Phase 1: Scoping phase

As noted in chapter 1, the main objective of this phase was to validate the five technology areas to focus the study around and to examine the extent to which the technology areas originally identified by Eurofound (that is, advanced robotics, autonomous transport devices, blockchain, virtual and augmented reality, and wearable devices) remained relevant to the goals of this study. In addition, the study team aimed to ensure that other technologies with potentially cross-cutting impact on the five technology areas – such as Artificial Intelligence and data analytics – were also considered.

As part of the validation exercise, the study team surveyed white and grey literature,[48] including journalistic and blog sources, as well as company reports and individuals' websites focused on horizon scanning of science and technology. Key sources of literature targeted by the study team included reports by international organisations (for example, OECD, World Economic Forum and World Bank), documents from European Commission sources (for example, European Political Strategy Centre), industry sources (for example, McKinsey, Deloitte, and Accenture), academic literature (for example, *Harvard Business Review* and *MIT Technology Review*), and sources from think tanks or third-sector organisations (for example, Pew Research Centre, Lisbon Council, and Nesta). Many of these sources report on the deployment of emerging technologies and applications and thus enabled the study team to assess the current and emerging landscape of game-changing technologies in relation to the objectives of the study.[49]

The study team initially scanned these sources to identify specific citations of current and emerging technologies that are having/are likely to have a disruptive impact. In total, 72 sources were identified to be examined through this quick scan of the literature. As part of the quick scan, the study team coalesced the identified technologies into broad technology area 'buckets' and conducted a 'strength of evidence' analysis of appearance of the technologies across the set of articles. This analysis assessed the frequency of the number of appearances of the technologies across the set of articles. Additionally, the nature of the evidence available (for example, peer-reviewed or grey literature) was also considered when determining the strength of evidence.[50]

Finally, having identified the technology areas, the study team discussed and validated the findings of the analysis with three 'cross-technology' experts. These scoping consultations focussed on establishing a cross-sectoral overview of the technology areas and their influence on key study themes, such as working conditions, employment prospects and productivity.

[48] 'White literature' refers to the content produced by commercial publishers. 'Grey literature' refers to content produced by entities (individuals or organisations) which do not publish content as their main task. For more details, see https://www.lib.uwo.ca/tutorials/greyliterature/

[49] Key search strings included the following terms and their combinations: 'game-changing technolog*', 'emerging technolog*', 'disruptive innovation', 'future of jobs', 'future of employment', 'future of work', 'future of productivity', 'new job skills for the future', 'future of workforce', 'future of services', 'future of services sector'. Additionally search strings related to specific service sectors – for example, transport, financial services, health and healthcare, retail, hospitality, logistics, pharmaceuticals, and entertainment – were used to augment the search as necessary.

[50] It is important to note that in the event of a consultation conducted with a wider set of stakeholder groups and a systematic review of the literature, the emerging strength of evidence could differ significantly.

Phase 2: Analysis and synthesis phase

Literature review searches

The study team identified a bibliography list for each of the technology areas. When the search was conducted, the emphasis was on articles that discuss the (potential) implications of the (future) technology applications in the services sector on the following aspects: work and employment (for example, in terms of skills and competences, working conditions, job quality, and employment relations) and production processes (for example, in relation to productivity, outputs, business models, and value chains). Although articles published before 2013 were considered where relevant, articles published from 2013 onwards have been prioritised. The study team focussed on building a corpus of English-language articles to inform the technology deep dives, but, where appropriate, a limited number of articles in other languages (for example, Dutch, French, German and Italian) were examined. Additional relevant articles were also ‘snowballed’ from the reference lists of some of the originally identified articles.

The generic search strings used for informing the initial literature search were as follows:

Generic search strings
([technology area] AND “service*”) AND (“work*” OR “employment” OR “skill*” OR “productivity” OR “working conditions” OR “work* relation*”)
([technology area] AND [specific service sector]) AND (“work*” OR “employment” OR “skill*” OR “productivity” OR “working conditions” OR “work* relation*”)

Exemplary search strings for the [technology areas] were as follows.

Technology area	**Search string**
Advanced robotics	(“Advanced robotics” OR “mobile robotics” OR “robot*”)
Autonomous transport devices	(“Autonomous transport devices” OR “autonomous vehicles” OR “driverless cars” OR “drones” OR “autonomous transport*”)
Blockchain	(“Blockchain” OR “distributed ledger*” OR ” dlt”)
VR/AR	(“Virtual reality” OR “augmented reality” OR “mixed reality” OR “immersive technolog*”)
Wearables	(“Wearables” OR “wearable*” OR “wearable technog*” OR “wearable device*”)

Limitations of the analysis

There are some caveats that need to be borne in mind when reading and interpreting the analyses presented in this working paper. This working paper is part of a larger study that includes the five potentially game-changing technology areas: advanced robotics, autonomous transport devices, blockchain, virtual/augmented reality, and wearable devices. Where relevant and supported by the discussion in the underlying literature, the study team has considered cross-functional and cross-sectoral implications of these game-changing technologies on each other. However, this working paper is intended to be stand-alone, and thus the emphasis is on the trends and socioeconomic implications observed in relation to blockchain.

During the scoping phase, additional technology areas – notably Artificial Intelligence and big data analytics – also emerged as important areas for consideration. However, the available literature suggests that these technology areas cover a broad spectrum of changes that could have a significantly transformative effect on the wider society and the economy. As a result, the study team has regarded these technology areas as ‘transversal’, or ‘cross-cutting’, and therefore to be considered in conjunction with the five core technology areas as needed – that is, whenever pertinent information about these technology areas emerged when the study team was collecting evidence, this was included in the analysis. For example, artificial intelligence appeared as a significant cross-cutting technology area that has been considered in the analyses conducted in relation to advanced robotics and autonomous transport devices. Any such discussion is informed by the relevance of these technologies within the key themes of this study and where supported by available evidence.

To identify the most relevant literature for the analysis, the study team adopted a rapid evidence review approach. Rapid evidence review does not aim for systematic coverage of the literature and thus aims to strike a balance between the available time and achieving sufficient depth of coverage in selecting the material. In doing so, the study team prioritised peer-reviewed literature for analysis. Grey literature was used to corroborate the findings, where relevant. Since the literature searches predominantly identified English language sources, where feasible the study team looked out for non-English material. Although the study team aimed to ensure inclusion of relevant material, it recognises that the rapid evidence review approach may result in important material not being identified in some cases.

For the interviews, the study team identified a long-list of experts drawing on its own network and subject matter expertise, and with inputs from its advisory board. A short-list was identified based on a consultation with Eurofound to ensure geographical coverage across Europe. The interviews were done based on availability of the external experts and to ensure a broad coverage of the themes related to the study. The study team has primarily used the expert opinion to complement findings from the evidence review. In some cases, expert testimony has been used to identify possible outcomes in the absence of suitable peer-reviewed material. In such instances, the study team has endeavoured to identify these outcomes as expert opinions rather than corroborated facts.

These game-changing technologies are still in the early stages of development, and their implications are still emerging. Therefore the discussion in this working paper combines qualitative analysis with quantitative data where available. Since long-term data on the adoption of technologies is not yet readily available, the study team has considered the available data in the form of patents, research publications, and R&D expenditure as signals of market interest and activity. To understand the general trends across the EU and in key non-EU countries, such as the USA, Japan and China, the study team referred to the latest available Eurostat data on patent activity and R&D expenditure. The timelines for this Eurostat data vary: the latest data on R&D expenditure is from 2016, and the latest patent data on high-tech sectors from 2013. The study team acknowledges that some of the trends observed in the study may change significantly once newer data sets on patents or R&D expenditure become available.

For analysing the trends specific to the technology areas, the study team used the patent landscape reports available via the World Intellectual Property Organization's (WIPO) website[51] and the data on patents and research publications published by the Tools for Innovation Monitoring (TIM),[52] created by the European Commission's Joint Research Centre (JRC). With both these sources, the study team did not have access to the underlying data, and thus the findings on patent data and research publications in relation to the technology areas presented in the study are a form of secondary analysis. Some patent landscape reports rely on the patent data available in public domain and thus do not incorporate the findings for the latest five years at the time of their publication. Although the study team endeavoured to ensure that latest patent landscape reports were referred to for each of the technology areas, as of 2018, some of the reports only cover the patent data until 2013. Additionally, the study team recognises that although the patents, publications and R&D expenditure data are useful to identify macro-level trends, these data do not provide the full picture of trends regarding the development and adoption of the technologies. This analysis is thus intended to inform the analysis of socioeconomic implications in relation to such themes as work, employment and productivity, rather than provide a definitive account of the potential outcomes of these technology areas on the services sectors in Europe.

Although the study team has, as far as possible, endeavoured to adopt a pan-European perspective in the analyses, it is important to acknowledge that the geographic scope within Europe in relation to data gathering for the study has been underpinned by the technologies themselves.

[51] See http://www.wipo.int/patentscope/en/programs/patent_landscapes/ for more details.

[52] See http://www.timanalytics.eu/ for more details.

Protocol for stakeholder interviews

Part 1: Introductory Questions

1. What is your current role and background?
    - For what areas do you have responsibility?
    - Do you have any conflict of interest in relation to this study?

Part 2: General understanding of the developments in the [technology area] landscape

2. With regard to the current state of play of [technology area] (in Europe and beyond), what do you think are some of the main trends that we observe?
3. What are some of the important driving forces for these trends that are enabling the development and adoption of [technology area], and why are these important?
4. What are some of the potential barriers to the development and adoption of [technology area], and how are they hindering the progression?

Part 3: Perceptions of the different socioeconomic implications of [technology area]

5. In relation to its potential to be a 'game-changing' technology area, how are [technology area] likely to have implications for the services sector?
    - In your view, which service sectors (and subsectors or specific industries) do you think present the current (and future) opportunities for the application of [technology area], and why?
    - Can you provide examples of applications of [technology area] in these sectors?
    - Aligned with the earlier question, in your view, which service sectors are least likely to be influenced by the development and adoption of [technology area], and why?
6. We would like to discuss the qualitative implications (positive and negative, direct and indirect) of [technology area] in terms of the following broader themes:
    - Work organisation, (workforce) productivity, and output/products
    - Employment
    - Skills
    - Individual working conditions
    - Collective employment relations
    - Are there any other implications?

Part 4: Perceptions of potential applicability of [technology area] to services sectors in Europe and beyond

7. In relation to some of the points that that you have raised so far, could you offer any observations that are specific to EU countries, or particular "geographical areas" in Europe?
    - How does the situation vary in / compare to different parts of the world?
8. More specifically, do you have any thoughts on potential 'real world' case examples to illustrate the application/implications of [technology area] in particular services sectors?
9. Could you recommend any relevant literature sources that we should consult as part of this study?
10. Do you have any thoughts on prospective quantitative data sources/indicators that we could draw upon?

Part 5: Additional insights – ethics and collective bargaining

11. Do you have any thoughts about the ethical implications concerning the deployment of [technology area]? Do you have any thoughts on the way increased use of [technology area] could change or influence the ethics of human-machine interaction at work would be welcome.

12. Do you have any thoughts about developments, if any, in collective bargaining with regard to changes in job descriptions or occupations?

Part 6: Wrap-up

13. Do you have any recommendations for other potential (technology/socioeconomic) experts and/or stakeholders that you think we should be speaking to?
14. Do you have any recommendations for potential case examples i.e. examples of [technology area] being used in practice and showcasing some of the implications we have covered as part of this discussion?
15. Based on your knowledge and experience of working in this field, is there anything else that you would like to add that we have not yet covered?

Interviewees

- European public sector expert
- Industry expert
- European Academic expert
- European third sector expert

Case example interviewees

- Nasdaq representative
- Two UNIC representatives
- IPNLF representative

The European Foundation for the Improvement of Living and Working Conditions (Eurofound) is a tripartite European Union Agency established in 1975. Its role is to provide knowledge in the area of social, employment and work-related policies according to Regulation (EU) 2019/127.