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EL IMPACTO DE BLOCKCHAIN EN SERVICIOS PÚBLICOS DESDE UNA PERSPECTIVA ECONÓMICA

PhD THESIS

THE IMPACT OF BLOCKCHAIN IN PUBLIC SERVICES FROM AN ECONOMIC PERSPECTIVE

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The Impact of Blockchain in Public Services from an Economic Perspective

El Impacto de Blockchain en Servicios Públicos desde una Perspectiva Económica

The Impact of Blockchain in Public Services from an Economic Perspective

DOCTORAL DISSERTATION

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Summary

The rapid transformation of our societies and the digital revolution, coupled with budgetary constraints, pose major challenges and opportunities for public administrations. Blockchain is an example of a so-called "disruptive technology," which is a technology that makes it possible to launch a new business model that targets an untapped market or revenue stream and expands to the point where it displaces established competitors. In the context of the public sector, blockchain proposes a new digital structure that enables the transformation of public services, oriented towards the creation of public value based on the capacity for collaboration and interaction between different actors. Specifically, a blockchain is a decentralised data structure, accessible and shared between nodes in a peer-to-peer network. Due to its decentralised structure, centralised points of vulnerability can be eliminated, and at the same time, it can be guaranteed that the information validated and stored in the blockchain cannot be modified unilaterally without the consent of the rest of the network. It also facilitates the introduction of encryption tools to ensure user privacy as well as the automation of a multitude of processes. Due to the intrinsic characteristics of blockchain, it has been identified as potentially ideal for both the implementation of new applications for public services and the transformation of current processes in public administrations. Blockchain may be particularly interesting and face unique challenges in its implementation in the public sector due to its potential for increased transparency, security, and decentralization, but also its complex technical nature and need for widespread adoption and collaboration. However, the technology still suffers from a premature stage of understanding, including a rigorous identification of the costs and risks associated with its implementation.

The central purpose of this doctoral thesis is to assess the impact of the incorporation of blockchain in public services from an economic perspective. From a multidisciplinary perspective, it identifies the potential costs and the major technological, socio-economic, cultural and legal challenges faced by both public administrations and citizens as a result of the introduction of blockchain for public services. It specifically examines the drivers for the adoption of blockchain in public services and the barriers to their uptake.

This doctoral dissertation is structured as follows. Chapter 1 sets out both the object, aims and contributions of the research. Chapter 2 conducts a systematic literature review on the introduction of blockchain technology in public services. The aim is to provide a comprehensive review of the benefits, costs, and risks of blockchain technology in public services from a multidisciplinary perspective from the insights of the literature. Chapter 3 seeks to contribute to overcoming one of the limitations found in the specialised literature, namely the scarce attention devoted to the role of public employees in the introduction of blockchain technology. To this end, the chapter assesses the attitudes of civil servants towards the acceptance of blockchain in public administration and its effect on trust. This is done through a vignette experiment which tests the effect of different blockchain configurations on civil servants' opinions on the acceptance of the technology and their perceived citizens' trust on the public administration. Finally, Chapter 4 addresses how to evaluate and compare the benefits and drawbacks of blockchain applications for the public sector thus filling the gap in the existing literature for a consistent framework. The chapter provides a multidimensional framework for evaluating the blockchain innovation process, which includes four dimensions: technological, socioeconomic, organizational-cultural, and institutional. This doctoral dissertation concludes with a discussion of the theoretical and practical implications of the findings of the previous chapters.

Despite the limitations of this research, discussed within each chapter, this work aims to increase the understanding of the benefits, risks, and costs of blockchain applications in the public sector. The literature suggests that the adoption of blockchain technology by the public sector has the potential to offer citizens personalized services, enhance public trust, and improve automation, transparency, and audibility. The use of blockchain technology in the provision of public services can also result in improved data security, integrity, and decreased operational costs and processing times. A government-issued blockchain-based identity, for example, can provide time and cost savings for citizens, businesses, and the public administration.

However, the results found in the thesis show that there are limitations to the disruptive impact of blockchain due to many technological, socioeconomic, organisational, and legal challenges. Blockchain still needs to integrate with existing systems to deliver added benefits and secure citizen information. The complexity of a wide range of public services exceeds blockchain current capabilities, particularly in handling the large number of transactions as well as the regulatory uncertainty surrounding its implementation. There are also concerns about ensuring the accountability and accuracy of electronic submissions without an impartial mediator. Additionally, the adoption of blockchain still requires collaboration between various stakeholders who must be able to set up, scale, and sustain the technology. In summary, this doctoral thesis highlights the still limited development of blockchain applications for the public sector and the need for researchers to continue collecting and analysing quantitative and qualitative data on blockchain use cases. Providing impact evaluations of blockchain-based solutions will increase the empirical evidence and improve the understanding of the suitability of the technology to solve a particular societal problem.

Resumen

La rápida transformación de nuestras sociedades y la revolución digital, unidas a las limitaciones presupuestarias, plantean importantes retos y oportunidades a las administraciones públicas. Las denominadas "tecnologías disruptivas", como blockchain, se refieren a aquellas que permiten la introducción de nuevos modelos de negocio que se dirigen a un mercado o flujo de ingresos desatendido y crecen hasta el punto de sustituir a los competidores establecidos. En el contexto del sector público, blockchain propone una nueva estructura digital que permite la transformación de los servicios públicos, orientada a la creación de valor público basada en la capacidad de colaboración e interacción entre diferentes actores. En concreto, una cadena de bloques (*blockchain*) es una estructura de datos descentralizada, accesible y compartida entre nodos de una red peer-to-peer. Debido a su estructura descentralizada, se pueden eliminar los puntos de vulnerabilidad centralizados y, al mismo tiempo, se puede garantizar que la información validada y almacenada en la cadena de bloques no puede ser modificada unilateralmente sin el consentimiento del resto de la red. También facilita la introducción de herramientas de encriptación para garantizar la privacidad de los usuarios, así como la automatización de multitud de procesos. Debido a las características esenciales de blockchain, esta tecnología ha sido identificada por la literatura como potencialmente idónea tanto para la implantación de nuevas aplicaciones en diversos servicios públicos como para la transformación de los procesos actuales en las administraciones públicas. Blockchain puede resultar especialmente interesante y enfrentarse a retos únicos en su implantación en el sector público debido a su potencial para aumentar la transparencia, la seguridad y la descentralización, pero también a su compleja naturaleza técnica y a la necesidad de una adopción y colaboración generalizadas. Sin embargo, la tecnología aún adolece de

una fase prematura de comprensión, incluida una identificación rigurosa de los costes y riesgos asociados a su implantación.

El objetivo central de esta tesis doctoral es evaluar desde una perspectiva económica el impacto de la incorporación de blockchain en los servicios públicos. Desde una perspectiva multidisciplinar, identifica los costes potenciales y los principales retos tecnológicos, socioeconómicos, culturales y legales a los que se enfrentan tanto las administraciones públicas como los ciudadanos como consecuencia de la introducción de blockchain para los servicios públicos. En concreto, examina los factores que impulsan la adopción de blockchain en los servicios públicos y los obstáculos que dificultan su adopción.

La presente tesis doctoral se estructura de la siguiente manera. El Capítulo 1 expone el objeto, los objetivos y las aportaciones de la investigación. El Capítulo 2 realiza una revisión sistemática de la literatura sobre la introducción de la tecnología blockchain en los servicios públicos. El objetivo es proporcionar una revisión exhaustiva de los beneficios, costes y riesgos de la tecnología blockchain en los servicios públicos desde una perspectiva multidisciplinar, a partir de las aportaciones de la literatura. El capítulo 3 pretende contribuir a superar una de las limitaciones encontradas en la literatura especializada, a saber, la escasa atención dedicada al papel de los empleados públicos en el proceso de innovación. Para ello, el capítulo evalúa las actitudes de los funcionarios hacia la aceptación de blockchain en la administración pública y su efecto en la confianza. Esto se hace mediante un experimento de viñetas, que pone a prueba el efecto de diferentes configuraciones de blockchain en las opiniones de los funcionarios sobre su aceptación de la tecnología y su percepción de la confianza de los ciudadanos en la administración pública. Por último, el capítulo 4 aborda la forma de evaluar y comparar

los beneficios e inconvenientes de las aplicaciones de blockchain para el sector público, llenando así el vacío existente en la literatura para disponer de un marco coherente. El capítulo proporciona un marco multidimensional para evaluar el proceso de innovación de blockchain, que incluye cuatro dimensiones: tecnológica, socioeconómica, organizativa-cultural e institucional. Esta tesis doctoral concluye con una discusión de las implicaciones teóricas y prácticas de las conclusiones de los capítulos anteriores.

A pesar de las limitaciones de esta investigación, discutidas en cada capítulo, este trabajo pretende aumentar la comprensión de los beneficios, riesgos y costes de las aplicaciones de blockchain en el sector público. La literatura sugiere que la adopción de la tecnología blockchain por el sector público tiene el potencial de ofrecer a los ciudadanos servicios personalizados, aumentar la confianza pública y mejorar la automatización, la transparencia y la audibilidad. El uso de la tecnología blockchain en la prestación de servicios públicos también puede mejorar la seguridad e integridad de los datos y reducir los costes operativos y los tiempos de procesamiento. Una identidad digital basada en blockchain emitida por el gobierno, por ejemplo, puede suponer un ahorro de tiempo y costes para los ciudadanos, las empresas y la administración pública.

Sin embargo, los resultados hallados en la tesis muestran que existen limitaciones al impacto disruptivo de blockchain debido a numerosos retos tecnológicos, socioeconómicos, organizativos y jurídicos. Blockchain aún necesita integrarse con los sistemas existentes para ofrecer ventajas añadidas y proteger la información de los ciudadanos. La complejidad de una amplia gama de servicios públicos supera las capacidades actuales de blockchain, en particular a la hora de gestionar el gran número de transacciones, así como la incertidumbre normativa que rodea su aplicación. También preocupa garantizar la rendición de cuentas y la exactitud de los envíos electrónicos sin

un mediador imparcial. Además, la adopción de blockchain sigue requiriendo la colaboración entre partes interesadas que deben ser capaces de establecer, escalar y mantener la tecnología. En resumen, esta tesis doctoral pone de relieve el todavía limitado desarrollo de las aplicaciones de blockchain para el sector público y la necesidad de que los investigadores sigan recopilando y analizando datos cuantitativos y cualitativos sobre casos de uso de blockchain. Proporcionar evaluaciones de impacto de las soluciones basadas en blockchain aumentará las pruebas empíricas y mejorará la comprensión de la idoneidad de la tecnología para resolver problemas sociales concretos.

Chapter 1. Introduction

I. Motivation and focus of the research

Public administrations around the world are facing a new set of social, economic, and political challenges. Among these challenges are those related to managing risk and uncertainty, ensuring trust and legitimacy in institutions, administration agility and efficiency, reflecting diversity, ensuring social inclusion, improving service delivery, together with the protection of privacy and data protection as well as a sustainable outlook in all its operations (Gerton & Mitchell, 2019). These challenges are coupled with the need to maintain balanced management through tight budgets. To try to find solutions to these problems, the incorporation of new technologies into the management of day-to-day work is recurrently cited as necessary and urgent to save money, avoid corruption, increase tax revenues, and augment economic efficiency. Indeed, over the last few decades, the digitisation of public administrations has become one of the priority strategies for governments around the world (OECD, 2016). The aim of the digital government is to bring public services closer to citizens and businesses, strengthening policy implementation in a transparent and innovative way. This process of digitisation of governments includes a toolkit of policy instruments in which new technologies play an increasingly important role (Hood and Margetts, 2007; Criado & Gil-García, 2019).

The innovation process on governments is a widely studied topic in the field of public administration (Greenhalgh et al., 2004; Hartley, 2016; De Vries et al., 2016, De Vries et al., 2018). The speed with which new information and telecommunication technologies have become an increasingly widespread reality in the current economy makes it necessary to study and better understand the adoption process as well as individual and group behaviours with respect to these technologies (Afsar & Umrani, 2020).

The introduction of new technologies in public administration processes has triggered important organisational changes in the past that have prompted extensive analysis. However, the transformations brought about by the introduction of information technologies (IT) from the late 1990s onwards are much more profound (Dunleavy et al., 2006). The generalization of IT systems implies that changes no longer affect solely administrative processes but notably conditions the whole terms of relations between government agencies and civil society. At present, the spread of open government practices inexorably challenges siloed and hierarchical work models within public administration and drives new models based on transparency, public engagement, and co-production (Clarke, 2019). Furthermore, there are technologies considered “disruptive” due to the assertion that, after being initially adopted in specific areas of economic activity for simple applications, they will continuously grow and eventually displace previous technologies. This will result in significant changes in the methods in which tasks are carried out, leading to cost savings and enhanced performance (Christensen et al., 2006; Lee et al., 2020)." The adoption of the so-called “disruptive technologies” on public agencies and the attitudes regarding the transformations they potentially create justifies the need for an actualization of the analysis.

A wide range of technologies that are currently being adopted are referred to as "disruptive technologies" (Christensen et al., 2006). Some of the best known are in fields such as Artificial Intelligence, robotics, Internet of Things, 3D printing, advanced Virtual Reality or Blockchain, the technology we will be focused on in this work. These technologies are so-called “disruptive” because of their ability to perform tasks in a fundamentally different way to how they were previously executed. Disruptive technologies may be particularly interesting in their implementation in the public sector due to their potential to transform government processes and systems, but also the need

for government organizations to adapt and change their traditional ways of working. Although they are set to bring about profound changes in the way processes are carried out, leading in turn to cost reductions and operational improvements, the concrete economic and social consequences are yet to be determined (Autor, 2015; Acemoglu & Restrepo, 2017; Acemoglu and Restrepo, 2020).

Blockchain technology and the public sector

A blockchain is the most well-known of distributed ledger technology (DLT) - both concepts are used interchangeably throughout this dissertation- that is formed by a series of blocks that record data using hash functions and that is stored and updated simultaneously on different nodes (Crosby et al., 2016). The unique characteristics of blockchain mean that it has begun to be considered as an attractive alternative for many procedures in the public sector (Lindman et al., 2020). One of the most interesting aspects of blockchain derives from its shared and decentralised structure. The fact that data storage is not restricted to a single central authority, as was traditionally the case in the provision of public services, creates numerous opportunities (Ølnes et al., 2017). These include the ability to improve data integrity and mutual trust, as well as reducing transaction costs and friction between intermediaries. The transparency inherent in the natural structure of blockchain allows users of the system to have reliable information on the current readiness of transactions, as well as a record of all transactions that have already occurred. The technology is also flexible when it comes to introducing restrictive permissions in terms of readability and freedom of action for individual users, making it potentially suitable for many applications. Another key feature of blockchain technology is the immutability of transactions embedded in the blockchain. As a general rule, when a transaction is added to the file or ledger, it is not possible to change it, unlike traditional data management mechanisms, where changes occur in a centralised database that is

subsequently accessed by all servers. Due to its decentralised structure and the continuous process of mining - validation and updating of data - the security of the information increases formidably (Shackelford & Myers, 2016). Therefore, blockchain has the potential to have a strong impact and generate opportunities for central governments, regional and local authorities to reduce operating costs, increase transparency and trust between governments and citizens, facilitate inclusion and give an organisational and financial boost to small and medium-sized enterprises (Ojo & Adebayo, 2017).

The characteristics of blockchain make it ideal for the transformation of existing processes in public administrations as well as the implementation of new applications in various policy sectors (Shen & Pena-Mora, 2018). However, the costs and risks of its implementation are numerous partly due to the premature stage of understanding from which the technology still suffers from. While researchers are rigorously studying the social and economic causes and consequences of the implementation of AI technology and robotization (Autor, 2015; Acemoglu & Restrepo, 2017; Brynjolfsson and McAfee, 2017; Wirtz et al., 2018; Acemoglu and Restrepo, 2020; Clifton et al., 2020), the adoption of blockchain by public and private bodies has gained much less attention.

The complexity of blockchain and its potential to disrupt existing power structures underscore the significance of the multidisciplinary approach adopted in this dissertation. A comprehensive evaluation of blockchain technology's impact in public services requires this type of approach that brings together experts from computer science, economics, law, and public administration. This approach takes into account the technical, financial, legal, and social implications of blockchain and enables informed decision making regarding its adoption and implementation. Partly due to the complexity along with the infancy of the technology, the evidence and practical policy understanding

of adoption factors of blockchain is still very scarce (Ølnes et al., 2017; Davidson et al., 2018; Janssen et al., 2020).

The TOKEN project

By the end of the 2010s, interest had grown in advancing the understanding of the real potential of blockchain in the public sector. The author and advisors of this dissertation have contributed to these advances through their participation in an international cutting-edge research project funded by the EU Commission entitled "Transformative Impact Of BlocKchain tEchnologies iN Public Services [TOKEN]".[1] This 3-year project, which ran from 2020 and terminated at the beginning of 2023, with a budget of nearly 4M€, was formed by a multidisciplinary consortium of 11 organizations from 9 European countries. It involves technology research organisations (IMEC[2], CERTH[3], Department of Telecommunications-UC), technology based non-profits (FBA[4]; VIL[5]), Social Science and Humanities experts (Department of Economics-UC), technology associations (INF[6], FF[7]), public policy think tanks (DRI[8]) and public agencies both as partners (Santander Municipality, Spain; Katerini Municipality, Greece) and as collaborating institutions (Leuven Municipality, Belgium).

The ultimate goal of 'TOKEN' was to develop an experimental ecosystem to enable the adoption of Distributed Ledger Technologies and to prove its value, via four highly replicable Use Cases, as driver for the transformation of public services towards an open and collaborative government model approach. In this respect, TOKEN provided

[1] https://token-project.eu/
[2] INTERUNIVERSITAIR MICRO-ELECTRONICA CENTRUM (IMEC), Belgium.
[3] ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS (CERTH), Greece.
[4] FUNDINGBOX ACCELERATOR SP ZOO (FBA), Poland and Denmark.
[5] VLAAMS INSTITUUT VOOR DE LOGISTIEK VZW (VIL), Belgium.
[6] INFRACHAIN ASBL (INF), Luxembourg.
[7] FIWARE FOUNDATION EV (FIWARE), Germany.
[8] DEMOS RESEARCH INSTITUTE OY (Demos), Finland.

a sandbox for testing novel processes and approaches that are required for a decentralised, cross-government and multi-actor architecture, combining the best of Distributed Ledger Technologies with Internet of Things, Big Data and Cloud technologies with the power of social tools, while addressing security, privacy and data protection requirements. The TOKEN project represented one of the largest research projects on blockchain technology funded by the EU along with the European Blockchain Service Infrastructure.[9] The present doctoral research directly links to TOKEN Working Package 4 whose objective was the evaluation of the economic and societal impacts and spillovers generated by the four Pioneer Use Cases.

II. Research questions and contributions

The central purpose of this doctoral thesis is to assess the economic impact of the incorporation of disruptive technologies in public services. From a multidimensional perspective, it will identify the potential costs and the major technological, socio-economic cultural and organisational challenges faced by both public administrations and citizens as a result of the introduction of these technologies. It will specifically examine the drivers for the adoption of disruptive technologies in public services and the barriers to their uptake. As a result, the following research questions are addressed in this dissertation: What are the main public services potentially affected by blockchain? What are the main potential benefits, costs, and risks of blockchain in public services for governments, civil servants and citizens? What determines public officials' opinions towards blockchain? How can a blockchain implementation be evaluated?

With this doctoral dissertation we intend to make progress beyond the state-of-the-art in scientific and practical terms by:

[9] https://ec.europa.eu/digital-building-blocks/wikis/display/EBSI/Home

- Providing a comprehensive analysis of the literature on the use of blockchain for public services, aimed at helping academics and policymakers understand, implement, and effectively communicate the technology's potential.
- Understanding public officials' role and attitudes on the acceptance of blockchain in public administration and on the effects of blockchain as regards trust in public administration and its services.
- Proposing a multidimensional framework for evaluating the introduction of blockchain-based solutions for the provision of public services.

III. Outline of the dissertation

Despite having a common theme, this dissertation consists of a series of essays that analyse the implementation of blockchain technology for the provision of public services.

In the second chapter, we conduct a systematic literature review on the benefits, costs and risks of the introduction of blockchain technology in public services. As discussed above, blockchain technology has aroused great interest in recent years among academics and technologists, due to the disruptive potential of its applications for society and the economy. The domain of public services is one of the fields in which blockchain may become a key technological infrastructure in the future. However, the expectation that innovative technologies will automatically bring about positive transformations can lead to overly optimistic approaches and biased assessments (Ølnes, 2016). Utopian claims aside, the benefits and risks of blockchain for public services need to be carefully considered (Aztori, 2015). In recent years, literature on blockchain in public services has started to emerge and is producing important insights. However, this research constituted a relatively scattered body of knowledge, and a comprehensive review of the benefits, costs and risks of blockchain in public services that brings together all existing insights

from a multidisciplinary perspective was needed. This is precisely the gap that the systematic literature review that constitutes this article aims to address. We show how the blockchain applications studied in the literature are distributed across a wide range of public services. However, the findings demonstrate that the majority of analyses in the literature either focus on case studies without including enough empirical evidence or on more theoretical studies that only briefly discuss potential benefits, costs, or risks.

The third chapter contributes to assess the attitudes of civil servants on the acceptance of blockchain in public administration and on the effects of blockchain on trust in public administration and its services. To do so, we conducted a vignette experiment among civil servants in different cities. We test whether different choices in blockchain configuration affect the opinions of civil servants, as well as their views on the opinions of their colleagues and citizens. Our vignette experiment is set in a hypothetical scenario related to the introduction of blockchain for a digital identity for local public service delivery. Based on an influential classification of blockchain configurations, we distinguish four different options in the blockchain configuration, along two dimensions: more or less "Public Write" (who has permission to access the network and enter data into the blockchain: all users or only civil servants), and more or less "Public Read" (who has permission to read the information found in the ledger: all users or only civil servants). The article hypothesizes greater acceptance of blockchain by public servants, the more public the blockchain configuration is (more open and permissionless input and access to information on the public ledger). The results of a sample of public officials in the City of Santander, Spain, show that a blockchain with “public write” mechanisms (any user can validate system registration processes) generates a higher level of acceptance, while “public read” (any user can see information

in the system) has no demonstrable effect, possibly because the benefits of transparency are neutralized by the possibility of criticism of public servants themselves.

The final topic we covered in chapter 4 is how to evaluate a blockchain application for the public sector. Early pilots introducing DLT to the public sector indicate that depending on the particular service, the effects of DLT may vary depending on the service impacted and may also be different for each of the involved stakeholders. As a result, there is a lack of a uniform framework to evaluate and compare the advantages and disadvantages of the introduction of DLT in various scenarios within government activities. This chapter provides a consistent multidimensional framework for evaluating the innovation process based on Key Performance Indicators, which encompasses four dimensions: technological, socioeconomic, organizational-cultural, and institutional (legal and political).

The core chapters of this dissertation have been delivered at national and international conferences and are either under review or already published in leading SSCI listed international peer-reviewed journals. The author of this thesis and first author of all the papers holds the primary responsibility for the content of this work. The primary author and the rest of the main authors of these publications were honoured to have the support and expertise of a team of esteemed professionals from the TOKEN project in the conduct of experiments and research for chapters 3 and 4. Table 1.1 provides an overview of the dissertation and its publication status.

Table 1.1: Overview of the dissertation

Chapter title	Publication status
Blockchain for Public Services: A Systematic Literature Review	Published in *IEEE Access*, 9, 13904-13921.
Explaining public officials' opinions on blockchain adoption: a vignette experiment.	Published in *Policy and Society*, 41(3), 343-357.
Blockchain in Government: Towards an Evaluation Framework	Under review in *Policy Design and Practice*

Chapter 2. Blockchain for Public Services: A Systematic Literature Review

I. Introduction

Blockchain is heralded as being ‘‘the next big thing’’ – one of the most important of the suite of technologies stated to have ‘‘disruptive’’ consequences for society and the economy in near-future applications. These technologies are labelled disruptive as it is claimed that, after initially taking root in simple applications in specific areas of economic activity, they will relentlessly scale upwards, eventually replacing previous technologies, and bring about profound changes in the ways in which processes are completed, delivering cost reductions and performance improvements (Cristensen et al. 2006), (Lee et al., 2020). Blockchain is actually a particular example of Distributed Ledger Technology (DLT, henceforth). Specifically, blockchain uses DLT to store information that has been verified by cryptography among a group of users through a pre-defined network protocol, without the control of a centralized entity or authority (Berryhill et al., 2018).

Blockchain is promoted as being a key asset for governments to keep up with future trends: it is claimed blockchain will profoundly transform public service production and delivery (Tapscott & Tapscott, 2016). However, the expectation that innovative technologies will automatically bring about positive transformations can lead to over-optimistic executions and biased assessments (Ølnes, 2016; Atzori, 2017). Putting aside utopian claims, the benefits and risks of blockchain for public services need to be carefully considered. A glance at the literature on blockchain shows that by far the majority of attention has been paid to bitcoin and other cryptocurrencies. For example, a search using Scopus indicates that, in 2019, nearly two-thirds (61.2%) of the total number of publications that focused on blockchain were about bitcoin. However, in recent years,

a body of scholarship on blockchain in the public sector has emerged. This literature is producing important insights into the potential of blockchain in the provision of public services. At present, these insights constitute a relatively disperse body of knowledge, in the sense that they are being produced across a broad range of disciplines, bridging both Sciences and Social Sciences. To date, a comprehensive review of the potential benefits, costs and risks of blockchain in public services, which brings together all the existent insights in a multidisciplinary perspective, is missing. It is this gap that this article seeks to address by conducting a systematic review.

At the same time, the number of projects and early-stage applications of blockchain initiated by governments and public administrations around the world are increasing[10]. Most of these projects and applications seek to use blockchain in order to improve economic efficiency, transparency, and the accountability of bureaucratic processes. Three main uses of blockchain in the realm of public services can be identified. First is the establishment of blockchain-based, international public infrastructures, that seek to improve coordination and information-sharing between governments, businesses and citizens from different countries. One example is based in the European Union, where the European Blockchain Services Infrastructure (EBSI) is being developed. EBSI aims to develop a public-permissioned blockchain infrastructure for application upon public services, such as sovereign digital identity, notarization, diplomas and trusted data sharing. Second is the further development of ‘‘Smart Cities’’. Here, blockchain is expected to be the missing piece of the puzzle to integrate Internet of Things technologies (IoT), AI, cloud computing and Big Data. Blockchain’s characteristics of immutability

[10]https://consensys.net/blog/enterprise-blockchain/which-governments-are-using-blockchain-right-now/?utm_campaign=ConsenSys%20Newsletter&utm_source=hs_email&utm_medium=email&utm_content=80467613&_hsenc=p2ANqtz--zOUwxuYK6daqZLBVjcSvsDfB415GmyrmqQ1XAqQ0DBWsYHR6cYWw7Fnjsuktv-dBE40ojH5MBFbBgDSRn1mh1AV0So0Oxmwv6hGdQVMHowXCOCQY&_hsmi=80467613

and traceability, along with its decentralized structure, are thought to help ensure progress towards a more efficient, secure, and transparent way of managing services and data. Third is supply chain management (Queiroz et al., 2019). According to the Global Alliance for Trade Facilitation, supply networks account for two thirds of the total cost of traded products, while seven percent of the total value is the cost of documentation processes alone (EMcompass, 2017). Blockchain is being used to address logistical complexity, by breaking down information silos, automating transaction and bureaucratic processes, increasing transparency, and guaranteeing authenticity along the supply chain. Public and private initiatives, such as komgo, the world's first blockchain-based platform for the commodity trade ecosystem, are expected to emerge in the near future[11]. A recent development regarding blockchain in public services is DApps, or decentralized applications, that run on a blockchain network, mainly Ethereum. DApps are similar to traditional Web applications but, instead of an application programming interface (API), DApps presents a wallet that communicates with the blockchain through smart contracts. Although the number of running DApps is still emerging, and focuses mostly on decentralized finance, marketplaces, games, gambling and crypto exchanges, it is probable that these applications will play a significant role in the future in the realm of public services.

The adoption of blockchain towards the provision of public services is expected to have important social, political and environmental implications. Blockchain can render societies more sustainable, understood as the harmony of three pillars: environmental, economic, and social (Paliwal et al., 2020). Blockchain has the potential to improve the access and transparency of public registries, management of, and access to, energy and water, citizen participation tools and international cooperation, among other advantages.

[11] https://consensys.net/blockchain-use-cases/finance/komgo/

By so doing, blockchain applications could have a positive impact on several Sustainable Development Goals (Rocamora & Amellina, 2018): reducing inequalities (objective 10), sustainable cities and communities (objective 11) and peace, justice and solid institutions (objective 16). At the same time, blockchain could also lead to costs, such an indiscriminate replacement of physical staff by highly automated, opaque processes or a general disempowerment of citizens caused by a concentration of power in dominant positions away from democratic scrutiny (Atzori, 2017). The direction, shape and intensity of the transformations brought about by blockchain are not pre-determined, and will depend on many issues, including blockchain's technical development, social acceptance, and political will.

In this light, the aim of this article is to compile all the existing scientific knowledge about the use of blockchain in public services. To do so, a systematic review of the literature is performed, which comprehensively collects what is known (theoretically and empirically) about the potential benefits, costs and risks of the use of blockchain in the arena of public services. The contribution of this article is to provide, to the best of our knowledge, the first systematic review of the literature specifically on the use of blockchain for public services. The results of this systematic review will help academics and policymakers better understand, execute and communicate the potential of this technology.

The role of public services has been fundamental as regards the creation of modern states and societies, since they contribute to territorial consolidation, social cohesion and political stability (Clifton et al., 2016). We define public services from a functional approach, referring to those services which are provided in the public or general interest. We opt to focus on ''public services'', rather than on the ''public sector'', since many

public services are delivered by non-governmental and private agents, or through mixed ownership partnerships, such as, corporations, inter-municipal cooperation, third sector or public-private partnerships (Clifton et al., 2019). ‘‘Public services’’, therefore, capture all of these activities, whether or not they are owned or controlled directly by the state. From the insights of this systematic review, this article sheds light on whether introducing blockchain is viable, feasible and desirable in public service production and delivery.

The introduction of an innovation such as blockchain is a complex process that presents diverse technological, socio-economic, legal, and cultural opportunities and barriers. The potential impact of the technology, therefore, will be different, depending on the specific public service in question. Furthermore, the implications of introducing blockchain into public services will differ—significantly—depending on the segment of society in question. For example, the implications of blockchain for governments responsible for managing or regulating the public service will likely be different to that of the civil servants who oversee public service production and delivery, as well as citizens, as users of public services. Therefore, our systematic literature review focuses on the following two research questions:

a) *What are the main public services potentially affected by blockchain?*
b) *What are the main potential benefits, costs and risks of blockchain in public services for (1) governments, (2) civil servants and (3) citizens?*

To answer these questions, we conduct a systematic review following Preferred Reporting Items for Systematic Reviews and Meta-Analyses or PRISMA guidelines (Liberati, 2009). This consists of a review of clearly formulated questions that follows systematic and explicit methods, including clearly stated objectives, a systematic search

to identify all the studies that meet the eligibility criteria, and a systematic presentation of findings (Moher et al., 2009).

The rest of this article is organized as follows. Section II provides a discussion of related work. Section III presents our research strategy, including the methodology used to conduct the review. Section IV presents the background results and the main characteristics of the records found. Section V identifies the main public services impacted by blockchain. Section VI discusses the benefits, costs and risks of blockchain for governments, civil servants and citizens. Finally, Section VII presents our conclusions, limitations, and suggestions for future research.

II. Related work

A small number of literature reviews on issues related to blockchain applications to services, processes and business models have been published. Though some of these articles include analysis of blockchain in a limited number of public services, the literature does not yet include a comprehensive analysis and discussion of blockchain in public services. The first wave of literature reviews of blockchain applications focused on its potential use in the cryptofinance and cryptocurrencies sectors, particularly, bitcoin (Crosby, 2016). Most of these studies were technical, and proposed changes to protocols, mining processes and privacy issues (Kiviat, 2015; Karame & Androulaki, 2016). To date, five systematic literature reviews have been published which analyse blockchain applications in the public sector (Shen & Pena-Mora, 2018; Scholl & Bolivar, 2019; Jaude & Saade, 2019; Bernal Bernabe et al., 2019; Rikken et al., 2019). Of these studies, Shen & Pena-Mora (2018) focuses on blockchain in the context of Smart Cities and includes analysis of a small number of public services associated with e-Government, energy, and education. Methodologically speaking, this article utilizes a component-based analysis

framework to classify blockchain practices by design, protocols and platforms, and provides a cross-sector analysis. Scholl & Bolivar (2019) inquires which areas blockchain is impacting regarding the public sector. However, instead of using a systematic literature review scheme, it uses the keywords mapping method. This article identifies the most commonly used words in the literature related to the study of blockchain in the public sector, and tracks how those evolve overtime. While this article identifies those public services where blockchain is being used, it does not provide insight into the benefits, costs and risks of each of these applications. Jaude & Saade (2019) covers blockchain applications in specific sectors, including a small number of public services, but most attention is paid to industrial (private) sectors. However, the list of public services covered is not comprehensive and this article does not analyse the specific context of the agents involved in the innovation process. Bernal Bernabe et al. (2019) does not review public services *per se*, rather, it reviews the current state-of-the-art on privacy-preserving mechanisms, and blockchain's applicability to eGovernment, eHealth and Smart Cities. Similarly, Rikken et al. (2019) reviews the public governance challenges of blockchain which may indirectly affect public services. In particular, it analyzes the governance challenges of different blockchain types, governance stages, and governance layers. Our article differs from these previous ones, in that it provides the first systematic review specifically focused on the context of blockchain and the universe of public services, provided by all levels of public administration, including: a comprehensive list of public services where blockchain is having an impact; a detailed discussion on the context of blockchain innovation in public services; and information on the benefits, costs and risks of blockchain in public services. These benefits, costs and risks are discussed for each kind of public service. In addition, they are disaggregated by agent, hence, benefits, risks and costs of blockchain are identified for government, civil servants and citizens. This is

discussed from the perspective of the diverse actors involved in public service provision, addressing their specific circumstances, motivations and concerns that may shape the innovation process. To this end, we identify the main benefits, costs and risks that governments, civil servants and citizens face as a consequence of the application of blockchain in public services. Our systematic review provides, therefore, the most comprehensive analysis of blockchain in public services to date, upon which further research, pilots and applications can build.

III. Research Strategy

Our systematic review follows PRISMA to ensure it is based on replicable and transparent steps that allow for the identification of all studies that meet the eligibility criteria and a systematic presentation of the findings. The checklist for each step is presented in the Appendix S.1.

A. ELIGIBILITY CRITERIA

Studies were included in the systematic review if they met all the following criteria:

- Type of Studies. Records considered should include discussion of the social impact (on governments, civil servants and citizens) of the use of blockchain in public services.
- Topic. Records included should deal with the use of blockchain technology in public services. We define public services from a functional approach, referring to those services which are provided in the public or general interest. Essentially, following the literature on this topic, public services are those services ‘‘for’’ the public, independently of whether

they are ultimately publicly or privately owned (Clifton & Díaz-Fuentes, 2010).

- Types of Participants. The scope of our systematic review encompasses the implications of blockchain for three possible types of participants: I. Governments, defined as the public bodies/entities directly or ultimately responsible of public service provision; II. Civil servants, defined as those employees in charge of the provision and/or regulation of the public service; III. Citizens, defined as the individuals who are the potential recipients of the service.
- Study Design. The interest of our systematic review is both on the theoretical and the empirical implications of the use of blockchain in public services.
- Language. We restricted our sample of studies to those written in the English language.
- Publication status. We included published peer-reviewed journal articles as well as books and book chapters.

B. SEARCH STRATEGY

We used three search strategies to identify scholarship on blockchain on public services. Our main search strategy was primarily focused on the two most well-known international repositories: Web of Science Principal Collection and Scopus.[12] For both sources, we first conducted a search of records containing the word ‘‘blockchain’’ in the

[12] We conducted the searches following the same criteria both in Web of Science and Scopus. When the options available from Web of Science and Scopus search engines were not exactly the same, we followed the closest available criteria.

title, abstract or keywords.2[13] Records had to be written in English and published as journal articles, book chapters or books, in the field of Social Sciences. Our search encompassed multidisciplinary publications also included in other fields such as Computer Science or Engineering. We found that interesting records included the word ‘‘public’’ (‘‘public service/s’’, ‘‘public sector’’, ‘‘public administration’’, ‘‘public agency/ies’’, ‘‘public value/s’’, ‘‘public organization/s’’, ‘‘public actors’’, etc.), and/or the word ‘‘government’’. In this light, we conducted a refined search in which the records included the word ‘‘public’’ (in any combination) or the word ‘‘government’’ in the title, abstract or keywords. This refined search resulted in 229 records from Web of Science and 150 records from Scopus. In order to minimize the number of false negatives, we developed a complementary search from Google Scholar. Records we searched for using Google Scholar had to include the word ‘‘blockchain’’, plus the word ‘‘public’’, or the word ‘‘government’’, in their title. This search resulted in 365 additional records. Searches were conducted in January 2020. A final search from the IEEE Xplore repository using the same criteria used for Web of Science and Scopus was also conducted. This search resulted in 244 additional records.

Two complementary search strategies were conducted. The second strategy led to a set of 35 additional records identified by blockchain experts. The final strategy consisted of updating the systematic review to include records from January 2020 to June 2020 using an innovative technique: an automatic search engine. ASReview is a new software that uses machine learning models in combination with active learning to facilitate the screening process of systematic reviews (van de Schoot et al., 2020). Firstly, we provided the software with a set of records identified from Scopus following the eligible criteria

[13] In Web of Science, this included both the keywords selected by authors and those (defined as KeyWords Plus) identified by its search engine.

described in the primary search process. Secondly, two of these articles were selected as relevant by the authors and used by the software as a head start. Then, the search engine showed the abstract of the most related article considering the ones already selected. The researcher chose whether to include or not the new record based on the screened abstract. Once the decision was taken, a new calculation was made, and the next most related article was presented. When several non-interesting articles appeared in a row, the researcher stopped the screening process, since the rest of these articles were expected to be non-relevant. This represents a significant advantage, especially for systematic reviews with substantial initial samples of records. This strategy using ASReview serves to carry out new systematic reviews as well as updates of published systematic reviews.

C. RECORD SELECTION

In total, our search led to 1,070 records. Two of the authors were jointly responsible for the screening process and final election. If there was disagreement about the eligibility of a article, this was resolved through discussion and consultation with the other two co-authors. Our selection process is presented in Fig. 2.1. In a first step, records were screened based on title, abstract and keywords. We excluded duplicates, as well as records that did not share all the required criteria (i.e., those not written in English, not published as journal articles, books or book chapters). In a second step, the remaining records were screened by reading their full content. We specifically followed the first two principles of the eligibility criteria regarding type of studies and topic. Records not dealing with the social impact (on governments, civil servants and citizens) of the use of blockchain in public services were excluded. For example, several studies analysed the application of blockchain from the point of view of business or the private sector and others only include computer modelling of the blockchain. Those articles, along with

records whose central feature was cryptocurrencies, were excluded. Ultimately, our record selection led to the inclusion of 92 studies in our systematic review.

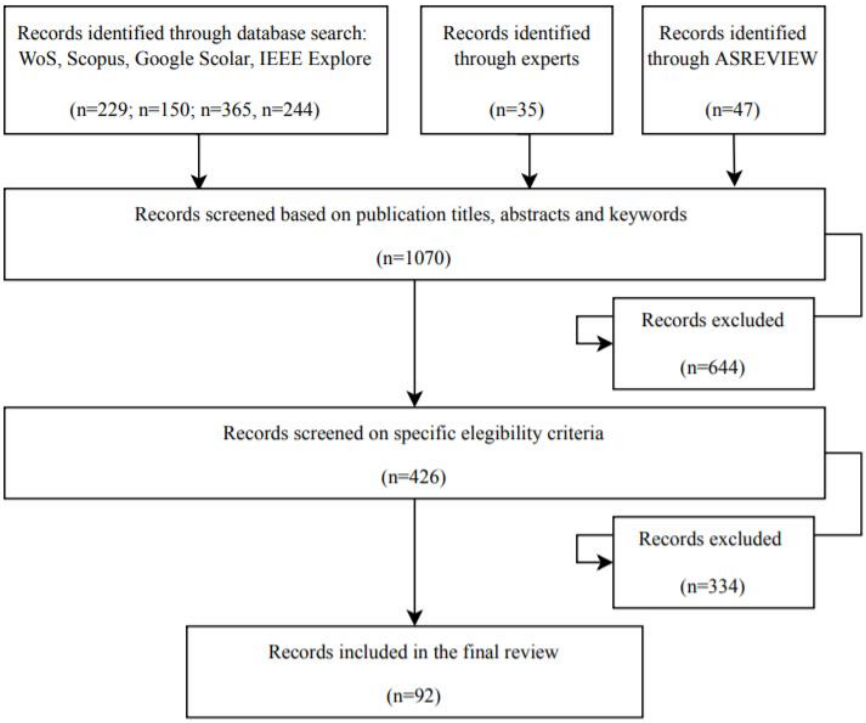

Figure 2.1: Flow diagram of the search strategy and record selection

D. CODING

We used NVivo12 to facilitate the organization and extraction of information required for a systematic literature review. We created a database of the records, coded them, and conducted the analyses. Nvivo is a software package built to analyse qualitative and non-structured data. It allows a more direct organization of text, video and audio using nodes, notes, cases, and conceptual maps. This process permits dividing the data into manageable segments while allowing rapid access to the relevant data when needed. The classification criteria can be introduced by researchers based on a priori field knowledge or with the help of available statistical language techniques, such as word counting, cluster analysis and other relational tools, including the Cohen's kappa coefficient (κ).

We used different tools to analyse the records of the systematic review. We used a word counting and a word cloud to quantify the most relevant concepts present in the literature. Additionally, we created different classifications in order to organize the data extraction process. Firstly, each record was catalogued regarding its general characteristics, including title, author, year, type of publication, method, journal and policy sector addressed. Next, we created a coding scheme, which we used to identify the benefits, costs and risks of blockchain for each of the three actors (citizens, government, civil servants).

The coding process was partly exploratory, since new categories for research methods and policy sectors were introduced whenever a record did not fit any of the available options. Regarding the research method, we differentiated five categories explained in the next section. Additionally, we identified 16 potential policy sectors for blockchain applications. The policy sectors are not mutually exclusive, which means that one record can examine one or several applications at the same time. Similarly, a study often discusses more than one benefit, cost and risk. Once all the information was classified, we used this to answer the research questions.

IV. General Results

A categorization of each record included in the systematic review, by authors, year, method, policy sector and objectives, is included in Appendix S.2. The distribution of records by year of publication (Fig. 2.2) shows the use of blockchain in public services is an emerging topic. The number of publications on this topic has increased sharply since 2016 (when the first two records on this topic were published), to 45 in 2019. The records are published mainly as journal articles (86) and, to a lesser extent, as book chapters (6).

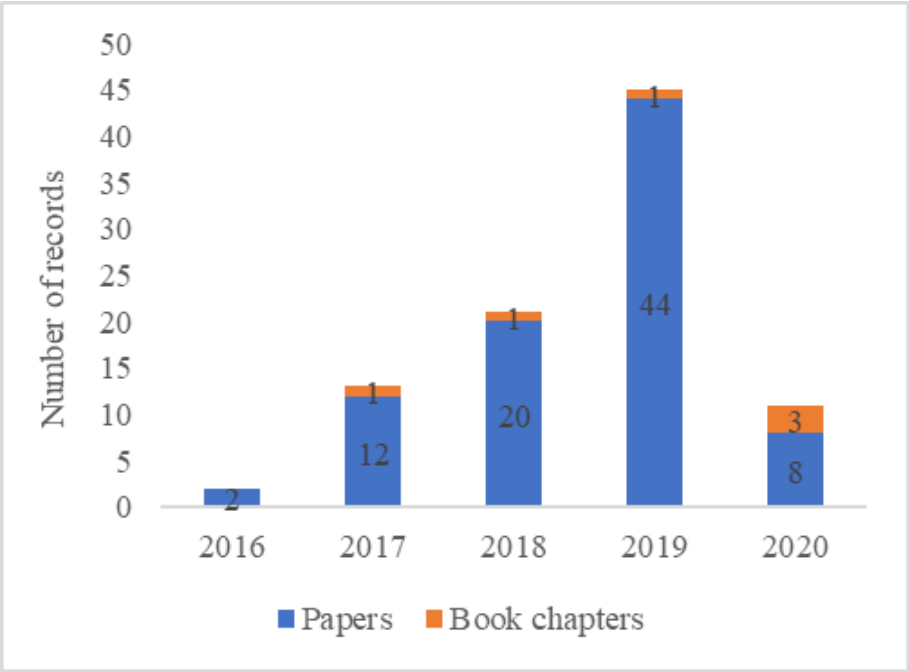

Figure 2.2: Distribution of records by year of publication

As shown in Table 2.1, most records are found in publications in the field of Social Sciences (74 records, 80% of total). Nearly two thirds of records are in publications in the field of Science & Technology (58 records, 63% of total). Some 40 records (43%) are in publications simultaneously included both in Social Sciences and in Science & Technology. The journals which contain the largest number of articles are Information Polity (6), International Journal of Recent Technology and Engineering (4), International Journal of Information Management (4), IEEE Access (3) and Sustainability (3). Computer Law and Security Review, and International Journal of Production Research include two articles each, respectively. The other journals contain just one article each. The articles are also very broadly distributed by area, which shows blockchain is being studied by scholars across a largely multidisciplinary spectrum.

Table 2.1: Distribution of records by field and journal of publication

Field of records	**Number** [a]
Social Sciences	74 (80%)
Science and Technology	58 (63%)
Journals with the largest number of articles	
Information Polity	6 (6%)
International Journal of Recent Technology and Engineering	4 (4%)
International Journal of Information Management	4 (4%)
Sustainability	3 (3%)
IEEE Access	3 (3%)
Computer Law and Security Review	2 (3%)
International Journal of Production Research	2 (2%)
Journal of Entrepreneurship and Public Policy	2 (2%)
Technology Innovation Management Review	2 (2%)

[a]A number of records are simultaneously included Social Sciences and Science and Technology areas. As a result, the sum of records in Social Sciences areas and records in Science and Technology areas is higher than the total number of records.

Records show a quite broad distribution across countries (Fig. 2.3). Records include authors from research institutions in 32 different countries. Research on this topic is led by the United States (23 records), followed by Australia, India and the United Kingdom, followed by Netherlands, Canada and China.

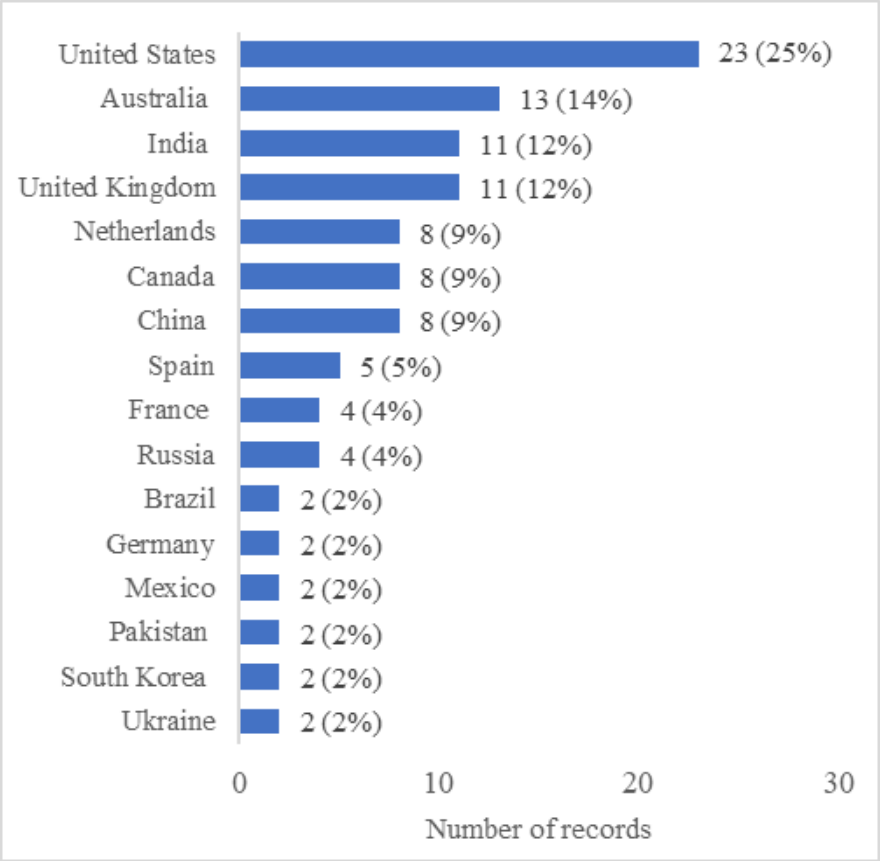

Figure 2.3: Distribution of records by country of publication

Records are predominantly theoretical (79) and only a few records are empirical (8). Among the theoretical articles we identify three different methods: Abstract Analyses, defined as those dealing with the topic of our review, but without a concrete or in-depth analysis; Theoretical Research Applications, defined as analyses of a concrete application of blockchain in a public service without a specific location; and Case Studies, defined as concrete and in-depth analysis of a case or multiple cases in specific locations, not already implemented. Empirical articles examine cases that have actually been implemented. Among the empirical articles, we identify single Case Studies and Multi-case Studies. Fig. 2.4 summarizes distribution of records by method of analysis. Records are predominantly Abstract Analyses (41%) and Theoretical Research Applications (29%). A significant number of records are Theoretical Case Studies (16% of total). Only a few records are empirical (8%), where one half are single Case Studies and the other

half are Multi-Case Studies. Five additional records are Systematic Reviews of related topics. These figures imply that albeit ex-ante analyses on the use of blockchain in public services are attracting increasing attention, quantitative analyses including empirical evidence on this issue are still scarce.

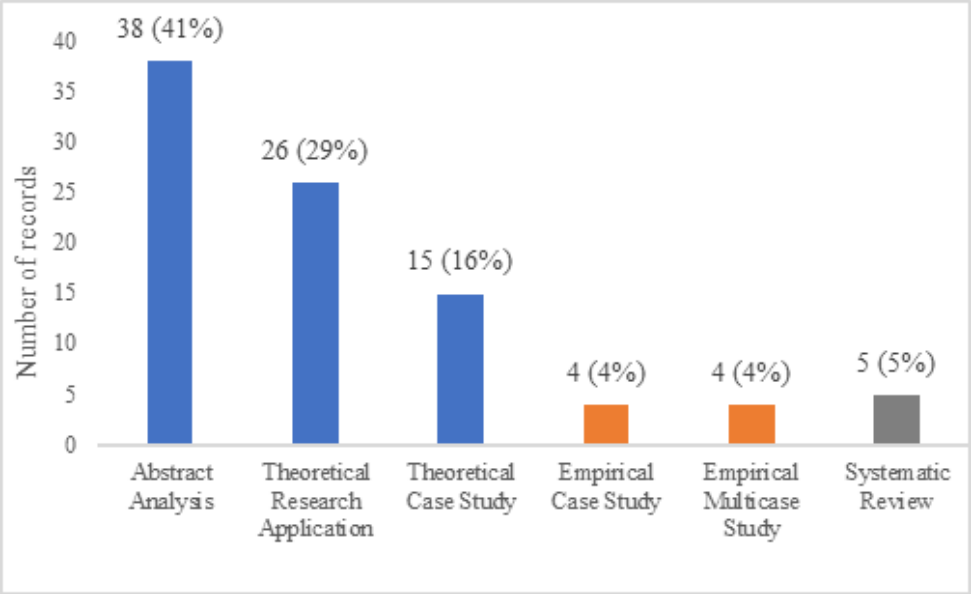

Figure 2.4: Distribution of records by method of analysis. Blue colour references theoretical methods while orange references an empirical method

Finally, Fig. 2.5 illustrates the word cloud of the systematic review, obtained using NVivo. This is based on the whole set of 92 records, after setting a limit of 500 words and a minimum of five letters per word. The words that are most cited are shown in a relatively larger size. The most commonly cited words are placed more centrally; less commonly cited words are further from the centre. Unsurprisingly, ‘‘blockchain’’ is the most highly cited word by far: it appears 11,109 times throughout the 92 records. The second most common word is ‘‘technology’’, with 4,067 appearances. The third word is ‘‘information’’, which appears 2,724 times. ‘‘System’’ (2,416 times) and ‘‘public’’ (2,402 times) are the other two words included in the top five. Among the ten most cited words, we also find the words ‘‘smart’’ and ‘‘government’’. As regards the three sectors for which we analyse the implications of the use of blockchain (governments, civil

servants and citizens), government(s) is the most mentioned (2,102 times), citizen(s) appears 609 times, and terms related to civil servant(s)[14] appear 98 times.

Figure 2.5: Word cloud based on the records included in the systematic review

V. Research question #1: what are the main public services potentially affected by blockchain technology?

We first describe the public services apt for transformation or disruption using blockchain for which the literature discusses relevant benefits, costs and risks. Records show a broad distribution across public services (Table 2.2). The sectors with the highest number of records are public records management (9) and healthcare (9), two public services where applications of blockchain technology appear promising. These are followed by a broad set of other sectors in which blockchain is seen to have significant applications, namely, international trade and customs (6), voting (5), environmental

[14] These include ‘‘civil servant(s)’’, public official(s), ‘‘government(s) official(s)’’,‘‘functionary/functionaries’’,‘‘bureaucracy(ies)/bureaucrats’’ and ‘‘public employee(s)’’.

protection (4), public procurement (4), food safety (4), digital identities (3), energy (3) and social protection (3).

Table 2.2: Distribution of records by public services potentially affected by blockchain

Public service	List of papers	Number
Records Management	[27-35]	9 (10%)
Healthcare	[35], [36-43]	9 (10%)
International Trade & Customs	[34], [43], [44-47]	6 (6%)
Voting	[35], [48-51]	5 (5%)
Environmental Protection	[52-55]	4 (4%)
Public Procurement	[35], [56-58]	4 (4%)
Food safety	[35], [59-61]	4 (4%)
Digital identities	[62-63], [78]	3 (3%)
Energy	[34-35], [64]	3 (3%)
Social Protection	[34-35], [65]	3 (3%)
Community Engagement	[66-67]	2 (2%)
Education	[34], [68]	2 (2%)
Public Accounting	[43], [69]	2 (2%)
Tax system	[70-71]	2 (2%)
Public Safety	[72-73]	2 (2%)
Recreational	[74]	1 (1%)

In the field of public records management, blockchain may facilitate making these records more accessible, thus reducing or eliminating delays in previously time demanding activities (Abelseth, 2018). Blockchain could also reduce the costs of registering information and ensure records are updated in near real time for everyone in the blockchain. Several administrations around the world, such as the governments of Dubai and Georgia, are already transforming their public records systems using blockchain (Kundu, 2019). Since data are maintained by every node in the network, any failure by the central authority does not compromise the data, reducing the dependence on information silos (Goonathilaake et al., 2018; Bhatia & Wright de Hernandez, 2019). However, even though the benefits are clear, regulatory uncertainty regarding blockchain is still a major risk. Regulatory authorities should enact the necessary conditions required for blockchain agreements to be sufficient for the formation of a legal contract (Lemieux, 2019). It is also necessary to establish ways to solve potential discrepancies between

blockchain information and the version of property titles previously found in a physical parallel system, such as the original property registry.

Healthcare is another public service where blockchain could bring great disruption. Thanks to improvements in traceability brought by blockchain, every health item could be marked by a unique code which would be used to check its authenticity and composition (Radanovic & Likic, 2018). Traceability refers to the ability to identify and monitor the information and events associated with a given good or service (Chang et al., 2019). Thus, governments would be able to reduce prescription fraud and better scrutinise the production of health products (Mariappan, 2019; Engelhardt, 2017). Regarding accountability, blockchain could also help with the storing of employee data for absence of leave, performance evaluation, and security measures for physicians— information that could be used to analyse the system and improve efficiency (Bhatia & Wright de Hernandez, 2019). Blockchain could be a solution to promote citizens' exercise of greater personal control over their health data, while ensuring anonymity. A blockchain solution could also improve patient-physician communication, while further engaging the patients in their own care. However, this would require technical training, particularly in the case of elderly patients (Radanovic & Likic, 2018).

Governments could also benefit from the use of blockchain in the tax system and the cooperation between tax authorities and custom agencies (Engelenburg et al., 2019). Due to blockchain's properties of traceability and transparency, tax authorities could detect fraud and errors faster and more effectively (Chang et al., 2019; Hyvärinen et al., 2017). In the context of customs, blockchain could be used to improve inter-agency coordination between customs agencies. Moreover, customs could use the information contained in the network to manage cargos more efficiently, expeditiously clearing the

ones already pre-screened and focusing examination on the ones specifically required. Regarding challenges, international standardization of blockchain legal requirements is essential for customs activities. Furthermore, it will be important to legally clarify which jurisdiction applies to international blockchains, and thus, which laws they should comply with (Allen et al., 2019).

Regarding voting and citizen participation, blockchain can enhance security, and facilitate transparency, while maintaining the privacy and anonymity of citizens (Johnson, 2019). This technology could not only record the recount in a safe and rigorous way, but also to do it faster and more efficiently than conventional mechanisms. In the blockchain, votes are recorded accurately and permanently in a way that no one can modify or manipulate. Citizens could even check that their votes are actually being counted (Borole et al., 2019). However, even with advanced encryption mechanisms, complete anonymity is impossible to achieve, since a node matching encrypted ballots with actual voters is still necessary (Zenin et al., 2019). In addition, there are scalability challenges regarding large-scale voting processes (Johnson, 2019).

Blockchain could also represent a radical conversion of the way environmental protection policy is made. The amount of data related to production recorded in blockchain coordinated with IoT would increase the capabilities in analysis and interpretation of environmental issues (Zhang et al., 2020). Governments would be able to trace and track major emission sources of carbon dioxide and methane quite rapidly, enabling more proactive measures being implemented to fight climate change. Apart from regulating pollution, blockchain could also be useful for monitoring and managing the exploitation of natural resources in order to ensure sustainability (Vilkov & Tian, 2019).

Making public procurement data accessible in a blockchain could improve the transparency and accountability of governments from the citizen perspective. This technology could help to address corruption and other concerns (Jarrahi, 2018). For example, in the case of public procurement by health systems, a traceable system such as blockchain would allow local hospitals to purchase health products in a decentralized way, while at the same time centralizing information regarding quantities and prices, and making them available to all parties (Borole et al., 2019). Furthermore, governmental entities can present their expenses on a public ledger, available for all citizens. This would not necessarily compromise privacy of agents, since a well-designed system would ensure anonymity (Abelseth, 2018).

Blockchain could also provide a significant improvement to governmental regulation practices and safety standards. A real-time tracking system, such as blockchain, would allow regulators to view all transactions and product history almost in real time (Howson, 2020). For instance, it would allow the identification of each food product and assign it with tamper-proof data such as provenance, organic attributes, and labour conditions. This would allow regulators to do their job in a more efficient and effective manner, assuring the reliability of records as well as streamlining access and processing processes (Allen et al., 2019). However, it is still unknown whether blockchain can efficiently manage the complexity of the information throughout large-scale supply chains (Sander et al., 2018).

Digital identity through blockchain is another key governmental activity that could be transformed into a more efficient and accessible public service. Blockchain may save governments vast sums of money on overhead costs related to physical office space, verification, and call centres (Wolfond, 2017). Estonian e-Residency is a good example

of where blockchain has changed the way citizens interact with government and other stakeholders, and how the administration has found a way to promote public and private Estonian services with very limited costs (Adeonato & Poumouri, 2020). In terms of social protection, blockchain could be used to disintermediate governmental transfers to citizens. This secure, direct and transparent way of giving transfers could transform the way social policy is done (Kundu, 2019). Finally, blockchain could also bring about sustainable and eco-efficiency improvements in the energy system, by providing greater information about the energy process. For example, blockchain could record the provenance and type of energy, and build an automated process including criteria based on this information. This would ensure this system would not only improve the security of the grid, but also result in benefits in terms of eco-efficiency, transparency and potential sustainability.

VI. Research question #2: what are the main potential benefits, costs and risks of blockchain in public services for government, civil servants and citizens?

Our approach studies the implementation of blockchain in public services from the different perspectives of the three main actors involved in the innovation process: Governments, civil servants and citizens, as shown in Fig. 2.6. For each actor, we identify the main benefits of blockchain for public services and then we discuss its negative consequences. Negative consequences can be classified into costs, the most probable ones, and risks, potential concerns, still to be confirmed. The order of presentation of benefits and costs/risks is based on the number of appearances throughout the articles of the systematic review.

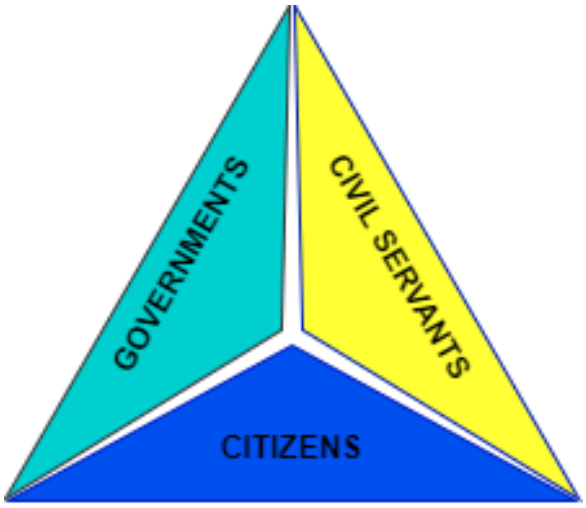

Figure 2.6: The three actors involved in the innovation process of public services

A. Governments

Table 2.3 identifies the most important benefits, costs and risks of the use of blockchain for governments. According to the literature, the most significant benefits are related to two major issues: economic efficiency and traceability. Meanwhile, the most significant risk of blockchain for governments is regulatory uncertainty.

Table 2.3: Main benefits, costs and risks for governments discussed in the literature

Governments	Number of records
Benefits	
Efficiency	37 (40%)
Traceability	25 (27%)
Decentralization	20 (22%)
Disintermediation	7 (8%)
Institutional innovation	4 (4%)
Costs and risks	
Regulatory uncertainty	29 (31%)
Scalability	18 (19%)
High energy consumption	10 (11%)
Lack of early frameworks	8 (9%)
High capital investment	7 (8%)
Not a substitute for institutional trust	5 (5%)

1) BENEFITS

The introduction of blockchain into public services has benefits for governments as regards its heralding of new ways of storing and sharing information that render processes more efficient, in the sense that results can be produced whilst using the smallest amount of resources such as time, material, capital or labour. Instead of lengthy, heavily bureaucratic procedures, blockchain proposes an automated means of storing data in a tamper-evident, secure, digital format. Blockchain can radically reduce the amount of human effort required for the operation of processes in many public services, leading to reduced costs (Fu et al., 2018). Additionally, this implies a reduction of every-day human errors (Allessie et al., 2019). In sum, all public services that include managing large sets of records and involve sharing information (both internally and externally) with citizens, business and other sectors, could be potentially transformed by blockchain and increase their efficiency (Chang et al., 2019).

The second major benefit of blockchain, according to the number of references in the literature, is traceability. The characteristics and attributes linked to a product could range from the location, application, characteristics associated with its production, such as inputs, origin, labour and production standards and environmental issues. Traceability could bring other benefits to government—including authenticity, property rights, origin, product and service safety, and accountability—across different sectors. Each record of product data could also contain details about the labour conditions under which production was carried out, among other characteristics. This means traceability could also help to promote better assurance of human rights and fair work practices (Saberi et al., 2019). Other potential benefits for government from blockchain include its decentralized structure, which helps guarantee greater data security, since it reduces their dependency on information silos (Fan et al., 2019). In this regard, once data is authenticated by the members of the blockchain, the information cannot be manipulated

by a node without being detected by the rest of the nodes, which limits the risk and damage of single points of failure. Furthermore, blockchain has the potential to reduce the time and cost of transactions avoiding third party intermediation. Blockchain can also improve regulation mechanisms and public safety standards through the collection of data regarding the production and distribution of products. Similarly, when data are transparent, this can potentially lead to an improvement in accountability of both government and non-government organizations.

2) COSTS AND RISKS

According to the literature, the most significant costs and risks of blockchain for governments are related to regulatory uncertainty. Interoperability is one of these risks. Interoperability refers to the ability to easily share information, operate, and transact across various systems. This is a fundamental problem to overcome, since the most probable scenario is that, instead of one single ledger (such as the internet), there will probably be multiple different public and private platforms which will require some kind of interoperability (Allen et al., 2020). Several potential conflicts arise between blockchain and current law in many countries (De Filippi & Hassan, 2019). It is still unclear which type of legal recognition would be conferred upon the data inside the blockchain, and whether it will require extra conditions (and which ones) in order to be recognized as legal (Lemieux, 2019). Another potential challenge arises from the fact that, as each node of a blockchain ledger is potentially located in a different part of the world, no consistent jurisdiction can be derived based on location (Davidson et al., 2018). More importantly, the disruptive properties of blockchain data might be legally problematic with respect to certain laws. For example, the fact that no one can easily

remove or modify information off the blockchain might conflict with several European Union laws, such as the 1995 Directive or the GDPR (Warkentin & Orgeron, 2020).

A second, major, risk that arises from the application of blockchain is the scalability constraint, which is intimately related to the efficacy and efficiency of blockchain. The scalability challenge refers to the scale and speed at which transactions can occur on a blockchain network (Dhagarra et al., 2019). This transaction velocity determines the time it takes to put a transaction on a block or reach a consensus between nodes. The more nodes needed to verify the blocks, the slower the validating process is. Furthermore, when more data is included and block size is increased, it will become more difficult to generate and propagate blocks (Xie et al., 2019). Thus, a trade-off is established between scalability and security. Blockchain technology is an immature technology in terms of scalability and still struggles to handle large number of transactions (Saberi et al., 2019). Blockchain also poses socio-economic costs for governments. Some consensus mechanisms, such as ‘‘proof-of-work’’, require every node to consume expensive energy resources in the mining process, causing increasingly high-energy costs. In order to reduce these costs, other consensus mechanisms have been proposed, such as ‘‘proof-of-stake’’, where validators prove their ‘‘stake’’ in the system through economic contributions that create disincentives for them to misbehave (Meiklejohn, 2018). Several other mechanisms have been presented, but many of them still lack sufficient maturity for implementation on a mass scale (Xie et al., 2019). Today, switching recording systems to a blockchain and scaling them to the level required to serve large populations could become expensive and damaging to the environment (Gabison, 2016). Another socio-economic cost involves the necessity of high capital investment. Previous studies focused on local applications of blockchain conclude that the current technological cost of switching to a blockchain might not outweigh the added

security it provides. In fact, the total initial capital investment is hard to estimate (Xie et al., 2019).

Finally, the introduction of blockchain as a trust mechanism also represents a risk. Although blockchain may offer many benefits for government, it cannot be considered an entirely trust-free system. In other words, blockchain is not a substitute for institutional trust and institutional infrastructure (Hyvärinen, 2017). In fact, countries with higher degrees of good quality public and civil services adopt blockchain earlier and more successfully (Adeonato & Pournouri, 2020).

B. Civil servants

Civil servants have received, to date, much less attention than governments and citizens in the literature regarding the implications of blockchain in public services (Ølnes & Janssen, 2017). In our systematic review, we find only eight records (10% of total) that mention benefits of blockchain from the point of view of civil servants. Most of these records focus on transformations of the tasks and increased coordination. Additionally, we find eight records (10% of total) that describe costs or risks of the use of blockchain in public services from their point of view. Table 2.4 shows the distribution of records according to the specific implications. These records focus mainly on the lack of necessary skills that staff have as the main potential cost/risk of blockchain.

Table 2.4: Main benefits, costs and risks for civil servants discussed in the literature

Civil servants	Number of records
Benefits	
Reduction of paperwork	5 (5%)
Reduction of every-day human errors	3 (3%)
Coordination improvements	3 (3%)
Costs and risks	
Lack of knowledge and skills	6 (6%)
Cultural change	2 (2%)
Reduction of jobs	2 (2%)

1) BENEFITS

One of the main benefits of blockchain for civil servants is associated with the transformation and automatization of the tasks carried out. Several documents focus on the effect that the use of blockchain in public services may have on the time-saving effect of the reduction of paperwork and bureaucratic interventions for administrative processes (Bhatia & Wright de Hernandez, 2019; Chang et al., 2019). Tasks conducted by civil servants may also benefit from the reduction of every-day human errors resulting from the automated means of storing data provided by blockchain (Allessie et al., 2019). Once blockchain is introduced, the tasks of civil servants in certain public services would change, and focus on developing, maintaining and governing the blockchain application. However, whilst the literature clearly states the benefits in terms of time and economic efficiency this may bring to governments, there are no in-depth analyses on how these changes may affect administrative processes and organizations. Neither do analyses report on how the nature of civil servants' tasks may change as a consequence of the introduction of blockchain in public services.

Another significant benefit for civil servants is the increasing possibilities for coordination. On the one hand, blockchain could be used to enhance inter-agency coordination systems through a shared ledger of administrative documents. On the other hand, the use of blockchain may enhance communication and coordination between civil servants and other actors involved in public service co-production and provision. For instance, in the field of healthcare, blockchain may enhance direct communication between physicians and pharmaceutical staff/professionals (Mariappan, 2019), as well as between physicians and their patients (Radanovic & Likic, 2018).

2) COSTS AND RISKS

A lack of necessary skills of civil servants is identified as the major cost for civil servants identified the literature. Clearly, all stakeholders will require training on blockchain technology for its successful application (Shang & Price, 2019). However, blockchain is a complex technology, and blockchain literacy constitutes a challenge not only for citizens-as-users, but also for civil servants as managers and providers of public services. Given that blockchain is a new technology, the number of experts, programmers and developers familiar with it and its possibilities for public services is limited (Thakur et al., 2020). Most civil servants do not have this sort of knowledge and experience, and public entities would need to train and hire technical experts and skilled personal in order to develop the application of blockchain technology (Hyvärinen et al., 2017). Moreover, the requisites for implementing successful training on blockchain technology would not be easy to accomplish, and would be limited to a few organizations, mainly at the national level.

Another related drawback is the cost associated with change in the organizational structure. Bureaucratic administrative systems governing any large institution are characterized by pre-defined processes and organized hierarchies (Allessie et al., 2019). It has been argued that these hierarchical structures are organized in order to facilitate the centralization of power in the hands of a few top civil servants (Long, 1949). The civil servants that benefit from the status quo will probably oppose internal resistance to the adoption of blockchain (Kshetri & Voas, 2018). This cultural change constitutes another potential cost and risk of the use of blockchain in public services.

Finally, another significant potential cost of the implementation of blockchain for civil servants could be a reduction of jobs. The promise of blockchain to automatize many

bureaucratic processes represents a threat to many civil servant jobs (Manski, 2017), and is likely to be highly uneven geographically and according to gender (Atzori, 2017). Jobs made redundant by the use of blockchain will be replaced by automated tasks and virtual labour. Low-skilled workers will be probably more intensively affected by this process. However, the transformation and consequences of blockchain for employment is an under-researched topic. Given the interest of this issue, this constitutes one of the major gaps on the literature on the use of blockchain in public services.

C. Citizens

The most relevant benefits, costs and risks for citizens identified in the literature are listed in Table 2.5. According to the literature, the most important benefits of the use of blockchain in public services for citizens are related to data security and transparency. The costs and risks for citizens associated with the use of blockchain in public services are diverse. The most important one, according to the literature, is related to potential security threats for blockchain data, discussed in 13 records (14% of total).

Table 2.5: Main benefits, costs and risks for citizens discussed in the literature

Citizens	Number of records
Benefits	
Security	40 (43%)
Transparency	36 (39%)
Self-sovereign of data	15 (16%)
Disintermediation	11 (12%)
Privacy	11 (12%)
Citizen participation	8 (9%)
Costs and risks	
Security threats	15 (16%)
Lack of flexibility of small contracts	11 (12%)
Not inherently trustworthy	7 (8%)
Risk of reidentification	7 (8%)
Minority rule	6 (6%)
Lack of knowledge and skills	6 (6%)
Lack of resources	4 (4%)

1) BENEFITS

The most important benefits of the use of blockchain in public services for citizens in the literature are related to security and transparency. The benefits for citizens related to security brought about by blockchain are derived primarily from the immutability of data. Immutability means that blockchains are based on an append-only data structure. Blockchain verifies every transaction through a consensus mechanism between nodes ensuring no single party has the unique power to alter it. As soon as a new block of data is verified and introduced in the chain, it is almost impossible to modify or remove this (Karale & Khanuja, 2019). Additionally, the decentralised characteristic of blockchain is fundamental for guaranteeing the integrity of information. Since data is not stored centrally, blockchain is not vulnerable to single security breaches (Warkentin & Orgeron, 2020). Furthermore, the process is developed transparently and accountable by every node (Myeong & Jung, 2019). Hence, technologically speaking, cybersecurity must arguably be a key advantage for citizens in countries that adopt blockchain technology.

As regards the benefits for citizens related to transparency, blockchain technology creates a new form of trust, allowing the public to easily monitor all actions taken inside the network (Rien & Susilowati, 2019). Transparency of blockchain, in addition to blockchain's properties of security and traceability, enables the public to track every item included in the blockchain back to its original inclusion, and is an open for validation of authenticity (Jarrahi, 2018). Additionally, in a transaction between citizens, it is very easy to verify whether one participant in the network is in possession of an exact and unmodified copy of the historical data stream. The trust based on a secure and transparent distributed ledger eliminates the need to hire, pay and trust a third-party entity to supervise transactions, allowing a further disintermediation of processes (Abelseth, 2018).

Another benefit of blockchain is associated with the idea that individuals will be able to exert greater control over their personal data. Blockchain is designed to give the owner of data a unique ID to access it over the blockchain network and the ability to share specific pieces of data they wish to share (Kundu, 2019). Furthermore, all these personal records can be preserved in the same system so that every individual will have a comprehensive digital identity, including all their personal records, which contains reliable and secure personal information. When used in this way, blockchain could facilitate the authentication of personal identity as well as, when necessary, the provision of personal information, such as education certificates or health status.

Data inside the blockchain are encrypted in different manners, in order to assure the privacy of users. Some of the data of government departments and public services providers are closely related to citizens' personal information. The merging of data from multiple sources may be used to form a ''full profile'' of each citizen, which clearly affects privacy (Fan et al., 2019). Using blockchain, different protocols can be used to encrypt the data and anonymise it, in order to avoid this risk (Potts et al., 2017). As a result of trust in the technology, the nodes in the system can exchange data without knowing each other's identity and personal information, so the privacy of each participating node is protected (Hou et al., 2018).

2) COSTS AND RISKS

Though security is a major benefit blockchain may bring, it also poses the most important costs and risks, according to the literature. At least one cost and one risk are identified. Recently, consensus mechanisms are being adopted other than ''proof-of-work'', with the aim of reducing energy and computational resources the blockchain network needs.

However, this solution comes at a cost, since it undermines the security of the network, as these alternative consensus rules are less strict. In fact, several successful attacks have already occurred in blockchains (Meiklejohn, 2018). Additionally, hackers could take advantage of breaking points caused by poor coding (Radanovic & Likic, 2018). Moreover, a risk exists that the ‘‘key’’ of the blockchain system is stolen, or that malicious coordinated attacks are made to the network (Carvalho, 2019). The possibility of stealing the key of the blockchain system exists, and may become grow in the future, depending on the development of computation.

Another cost of blockchain comes from the fact that, in an early stage of development, it lacks sufficient flexibility to adapt to distinct situations (De Filippi, 2016). While immutability is a benefit for certain public services, it is also a cost for citizens. Blockchain data cannot be easily deleted or changed. However, a judicial authority could demand that certain information should be deleted from the server, due to right-to be-forgotten laws (Abelseth, 2018). Copyright materials may face similar problems when published in a blockchain without authorization. However, while a ‘‘hard fork’’ (a unilateral change of internal rules by the system managers) would be able to change the validity status of data blocks, it cannot actually remove them from the internet, and still would not satisfy certain laws such as GDPR (Bhatia and Wright de Hernandez, 2019). Furthermore, the use of ‘‘hard forks’’ may end up challenging the credibility and trust on the blockchain, since it debunks the horizontality principle.

In addition, blockchain relies upon the data that has been validated by the nodes, and thus, it is not inherently trustworthy, since the technology does not guarantee information quality, but only the accuracy of the procedure. The quality and usefulness of the blockchain technology is ‘‘as good as its users’’ (Engelhardt, 2017). Therefore,

substituting human (or multiple human) supervision by a blockchain in processes that demand high levels of accuracy represents an important cost.

Although encryption is useful to increase the privacy of blockchain users, the risk of reidentification is still present. Though each user in blockchain is linked to a public pseudonymous address, due to transparency of blockchain, the transactions are available to the public, and information is explicitly visible by all network participants (Xie et al., 2019). An increasing amount of research suggests it is possible to de-anonymize individuals by using transactions details (Nicholson, 2017). The more transparent the blockchain is, the bigger the risk of reidentification (Chang et al., 2019).

Blockchain is still a complex technology that requires specialized knowledge for creation and management. A minority of experts dictate the rules of the system and how it is governed: this constitutes an additional risk for citizens. Only a few individuals can modify the code, and the design of the system will likely represent their interests (Atzori, 2017; Ølnes et al., 2017). Depending on the nature of the blockchain, sudden ‘‘hardforks’’ can transform the way the network works, making it mandatory for the users to comply with the new rules. This position of power threatens the promises of decentralization and horizontal decision-making of blockchain. In the case of permission-based blockchains, private companies usually play a fundamental role in shaping how a blockchain infrastructure functions. Therefore, they could hold dominating powers, diminishing the capacity to integrate enough checks and balances into the blockchain network (Johnson, 2019).

Moreover, the ‘‘usability’’ of blockchain technology is still a crucial barrier for mainstream adoption (Chang et al., 2019). The term usability refers to the degree of ease with which products such as software and other technological applications can be used to

achieve required goals effectively and efficiently. Lack of knowledge and technical skills impede several social groups of citizens to immediately benefit from the use of blockchain. Thus, it is imperative to improve intuitive blockchain interfaces and to assure some degree of blockchain literacy before it is introduced to the wider public. Finally, blockchain models and proposals require having access to internet connectivity and digital devices. which is not always the case of most citizens in certain contexts, especially in less developed countries (Dhagarra et al., 2019; Nicholson, 2017).

VII. Conclusions and recommendations for future research

Blockchain is considered one of the most important disruptive technologies as regards its potential to transform business and society in the near future, including the provision of public services. Even though blockchain is still a nascent technology, scholarship on the consequences of blockchain adoption is growing.

A. Contributions of this work

The major contribution of this work consists of providing the first systematic review of the literature on the use of blockchain in public service provision, analysing the specific benefits, costs and risks of the three key agents of the innovation process: governments, civil servants and citizens. The systematic review follows the PRISMA criteria, through clearly stated objectives and an eligibility criterion to identify studies. We provided a systematic presentation of our findings. We identified 92 published records from journals and books that cover blockchain applications on public services. Among them, we classify 79 as theoretical articles and eight of them as empirical, while another five were systematic reviews on related topics. The articles are broadly distributed by field and area of study, which shows that blockchain applications is being currently addressed from a multidisciplinary perspective.

We found blockchain applications are broadly distributed across a range of public services. We identified 16 different public services potentially affected by the introduction of blockchain. The public service that concentrates the greatest number of studies is public records management, which is addressed in 9 records. Blockchain is bringing to this public service efficiency improvements regarding time and costs and a more secure infrastructure, even though several uncertainties related to regulation arise in the process. The second most discussed public service is healthcare, where blockchain could improve the system through traceable tools, accountable transactions and more control over personal data. Other public services identified in this systematic review and discussed in more than two records are international trade and customs, voting processes, environmental protection systems, public procurement, food safety, digital identities, energy and social protection.

We propose an organizational approach to the benefits, costs and risks of blockchain in public services, by classifying the actors of society involved in the innovation process. We observe, first, that two actors concentrate the bulk of attention in the literature: governments and citizens. Civil servants receive less attention. Next, we analyse the implications of the use of blockchain in public services for each of these actors. For governments, we find that the most important benefits of blockchain are associated with efficiency and traceability, whilst the most significant costs and risks are related to regulatory uncertainty (interoperability and standardization, legal recognition of data, incompatibility with laws, jurisdiction requirements and accountability), and scalability. For civil servants, the literature discusses benefits associated with the transformation of tasks carried out and increased possibilities for coordination, while the most important costs and risks cited are linked to the lack of necessary skills, the change in organizational structure and jobs cuts. Finally, the literature on the impact for citizens

focuses especially on benefits of blockchain related to security and transparency, whilst also a range of different costs and risks (in particular, those related to potential security threats) are discussed.

Several implications can be extracted as regards blockchain applications in public services, from the point of view of benefits, costs and risks for governments, civil servants and citizens. In the case of governments, blockchain has the potential to improve the economic efficiency of bureaucratic processes and data management. For example, blockchain-based land title registry in Georgia, where the registration of extract is now 400 times faster and the reduction of costs is over 90%, is an example of a successful case (Eder, 2019). Estonia is another successful example of the use of blockchain as part of its e-government strategy on registries and administrative procedures, which have improved processes around tax, judicial, health and commercial code systems[15]. Moreover, services mainly focused on notarization that utilize blockchain as an append-only registry are close to market maturity. However, other disruptive services that make the most of the shared database and the traceability feature of blockchain still face many hurdles. Regulation is a major challenge, including setting recognizable standards, regarding the applicability of blockchain for these cases. A key implication, then, is that there is an urgent need to establish an initial set of methods, common practices, as well as technological and legal semantics at the highest administrative level, in order to ensure legal certainly for future blockchain applications. In addition, as identified in our article, government itself needs to enact a transformation of existing processes and structures in order be prepared for the disruptive potential of blockchain. This task will require dialogue and coordination from stakeholders in the network which will best be led by governments and, ideally,

[15] Estonia: E-Governance. Accessed: Oct. 21, 2020. [Online]. Available: https://e-estonia.com/solutions/e-governance/

international institutions. The EU Blockchain Observatory & Forum is a promising example of this sort.[16]

In the case of civil servants, reduction of red tape, paperwork, and every-day errors, are the main benefits blockchain applications will bring to public services. Additionally, improved coordination between agencies implies a reduction in the time employed by civil servants on tedious tasks through easier and faster access to information already uploaded to the administration network. Consequently, the quality of jobs could also increase. However, blockchain applications face several risks as regards its impact on civil servant jobs. Scholars have suggested disruptive technologies, including blockchain, artificial intelligence and machine learning, may pose a threat to unemployment without the support of appropriate public policy (Acemoglu and Restrepo, 2020). The need for reskilling to accommodate the new technology implies that substantial investments will be required. Potential rejection of new technology may need to be overcome with ensuring technology is human-centric as regards its design, including simple interface and easier ways of resolving and reporting potential errors (Clifton et al., 2020).

From the point of view of citizens, the main benefits identified regarding the adoption of blockchain in public services are data security, transparency of public administrations and greater control of personal data. The use of blockchain for national land registries, healthcare systems and digital identities, are positive examples of how blockchain can eliminate excessive bureaucracy and physical displacement to the city hall in favour of remotely digital alternatives. Moreover, having a greater control over their personal data allows citizens to preserve their own privacy in a more effective manner

[16] EU Blockchain Forum. Accessed: Oct. 21, 2020. [Online]. Available: https://www.eublockchainforum.eu/

and enhance their trust in the service provider. The COVID-19 pandemic has increased the attention paid to blockchain for supply chain management in times of uncertainty (Shukla et al., 2020). However, because blockchain-based services are mostly in a pilot phase, or operate on a small scale, these gains are only starting to be made visible. Despite recent progress, much more needs doing on the technical side regarding data security and flexibility of smart contracts. Finally, it is important to note that blockchain is just another piece of the digitalization strategy of public services. Thus, the added value of blockchain for citizens does not depend on blockchain alone, but from the successful articulation of the different technologies and functionalities in a whole system for public services of the future.

B. Limitations

The main limitations of this review are determined by the very infancy of the literature on blockchain in public services. One of the major shortcomings of the literature is a lack of empirical analyses on blockchain in public services (Ølnes et al., 2017). As the application of this technology, particularly in public services, is still at a very early stage, most of the analyses are abstract or theoretical: most of them focus on discussing potential benefits, costs or risks of blockchain in public services without entering into specific cases already implemented, or focus in case studies without including sufficient empirical evidence. Clearly, until there are large scale implementations in government, there will be a lack of empirical research on real-world applications.

Regarding this article, even though the search and screening process has been carried out in great detail including three major datasets and recommendations of specific records from field experts, there is a possibility that some high-quality work has been left out. Additionally, the screening and reading processes inevitably carry with it a dose of

subjectivity. Therefore, both potential selection and information extraction bias could be identified. Finally, this article focused on the use of blockchain application from the social and economic perspective, leaving aside the more technical and computational aspects.

C. Recommendations and future research

We have identified four specific issues which are neglected in the current literature and deserve further attention in the quest to develop a more coherent picture of blockchain for public services.

Recommendation 1 (From Theoretical to Empirical Analyses): As the number of projects and applications of blockchain increase, research on the use of blockchain in public services needs to move from descriptive/theoretical studies to empirical analyses of actual implementation and assessments based on real cases, in order to provide policymakers with ready-to-use material. Hence, it is important that researchers track developments and collect a greater amount of qualitative and quantitative data on blockchain applications to provide rigorous analysis of the benefits, risks and costs of blockchain in public services. In order to frame the initiative, two aspects should be carefully analysed. First, the internal validity of the case, consisting of an evaluation of whether the blockchain has provided a satisfactory and adequate solution to the initial problem and a comparison of this with different previously potential options, needs to be completed. Secondly, the external validity of the analysis needs to be verified, meaning whether the specific characteristic of the context makes this a comparable example for other technological, socio-economic, legal and cultural contexts. A rigorous evaluation of use cases based on these two aspects will lead to a better understanding of the potential of blockchain in public service provision.

Recommendation 2 (Diversity of Empirical Methods): We also encourage more cross-sectoral designs to expand our understanding of the differences in the use of blockchain between private and public sector organizations and between different public policy sectors. Further cross-national research can shed light on the antecedents and pre-conditions of public administrations for blockchain adoption. Finally, although there is no guarantee that the quality of external evaluation is better than internal reports (Conway & Lance, 2010), an overrepresentation of the latter can cause biased results. Thus, a greater number of external evaluations of the innovation process are needed.

Recommendation 3 (Address Major Technical Barriers): Much work remains for researchers to do in the technical field. Even though recent progress of the technical aspects of blockchain has been made, the development of blockchain technology is still at an early stage when comes to large-scale applications. Scalability is still one of the main constraints surrounding blockchain initiatives for public services. In the future, less computational demanding consensus algorithms are necessary, particularly when the blockchain aims to manage a large number of users and transactions. Energy consumption requirements also need to be reduced and transaction costs need to be low and predictable, otherwise public initiatives will be very hard to justify. In this regard, diverse technical and governance specificities need to be available, since different problems will be addressed by different sorts of blockchain. Moreover, technical experts and research institutions need to coordinate interoperable standards, which are essential to assure that all the technical advances take advantage of indirect effects and economies of scale.

Recommendation 4 (Differentiate Between Types of Blockchain): Future studies need to adopt a simple shared scheme and identify which is the preferable type of blockchain given the specificities of the specific public service and the problem

addressed. Literature on blockchain for public services has paid very little attention to how the different characteristics of blockchain infrastructure might be implemented to achieve different policy objectives. This represents a major flaw in analysing blockchain for public services, since the specific characteristics of permissioning and infrastructure governance have important political and economic implications, such as transaction costs, performance, privacy, incentives and control of the network. A public-permissioned network, where citizens and entities must identify themselves, and where there are no artificial barriers of entry for citizens, seems to be a promising proposal for a blockchain-based infrastructure for many public services in the European Digital Single Market (Ruiz, 2020; Geneiatakis et al., 2020). However, this might not be the case where established institutions are not sound, or where the legal requirements due to the characteristics of the information shared or the existing regulations are lax. Finally, in this respect, another useful avenue for research will be the analysis of the implications of potential DApps for public services developed in Ethereum and other decentralized platforms.

Recommendation 5 (Focus on Consequences for Civil Servants): While the existing literature on the use of blockchain in public services has focused on consequences for governments and citizens, research on the consequences for civil servants – the individuals responsible for public service provision – have been under-researched. New studies on the impact of a disruptive technology such as AI on the future on jobs are emerging (Jarrahi, 2018). In the case of blockchain, some of the key questions that still need to be adequately researched are the following: the consequences of blockchain on job displacement and job quality; the role of policy in shaping the consequences of new technology on jobs; and the new skill sets that are required in order to manage the infrastructure, governance and organizational structures of transformed public services.

To this end, a wide range of research methods will be useful, including case studies, comparative analysis, structured and semi-structured interviews and survey methods, and the use of quantitative data to measure macro-effects.

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Chapter 3. Explaining public officials' opinions on blockchain adoption: a vignette experiment

I. Introduction

Public administrations around the world are facing a new set of social, economic, and political challenges. Among these challenges are those related to managing risk and uncertainty, ensuring trust and legitimacy in public institutions, and increasing the agility and efficiency of institutions, whilst striving for diversity, social inclusion, and improved service delivery. All these challenges are coupled with the need to maintain balanced management through tight budgets. The incorporation of new technologies into the management of day-to-day work of public administrations as a means of providing solutions to these challenges is conceived to as a way to save money, avoid corruption, increase tax revenues and increase economic efficiency (Gil-Garcia et al., 2018). Indeed, the digitalization of public administrations has become a strategic priority for public administrations around the world (OECD, 2016). E-government includes a toolkit of policy instruments wherein new technologies play an increasingly important role. Within these new technologies, one sub-set that is currently being adopted is referred to as "disruptive technologies" (Christensen et al., 2006), such as Artificial Intelligence, robotics, Internet of Things, 3D printing, Advanced Virtual Reality and blockchain. These technologies are said to be disruptive because of their potential to perform tasks in a fundamentally different way. Disruptive technologies are set to bring about profound changes in the way processes are carried out, leading in turn to cost reductions and operational improvements. However, the concrete economic and social consequences of their implementation are yet to be determined.

This article analyses the introduction of blockchain into public administration. A blockchain is an information technology that is mainly used to register transactions that

require authentication and trust. Blockchain consists of a series of blocks (collections) of recorded data which are stored and updated simultaneously by different nodes (parties) within the ledger (bookkeeping) (Crosby et al., 2016). Since blockchain does not rely on a central point, the information validated and stored within the blockchain cannot be modified unilaterally without the consent of the rest of the network. Blockchain's specific characteristics make it a strong candidate to disrupt many public services. The ability to trace items from the point of origin to the point of delivery, ensuring that the information recorded has not been tampered with, has great transformative potential in sectors such as medicine or food distribution (Kouhizadeh et al., 2021). This advantage, together with its capacity for transparency, anonymity, and process automation, makes blockchain potentially ideal for administrative processes, public procurement and record-keeping (Cagigas et al., 2021). In this respect, one of the most advanced large-scale use cases is EBSI (European Blockchain Services Infrastructure), which aims to use blockchain to create cross-border, decentralized services for European public administrations, allowing citizens to control their own identity whilst, simultaneously, standardizing and streamlining interactions with the EU and national administrations.

Despite these advantages, the costs and risks of implementing blockchain are significant, such as the infancy of the technology, regulatory uncertainty and scalability problems (Batubara et al., 2018). As in the cases of other technologies, such as Artificial Intelligence and robotization (Clifton et al., 2020; Acemoglu & Restrepo, 2020), successful blockchain adoption requires workers' acceptance of the technology. However, the literature shows that acceptance depends on a range of contextual factors (Janssen et al., 2020).

In this light, this article contributes to understanding public officials' opinions on the acceptance of blockchain in public administration and on the effects of blockchain as regards trust in public administration and its services. To do so, we conduct a vignette experiment on public officials in the city of Santander, Spain. We test whether different options in the configuration of blockchain affect public officials' opinions as well as their views on their colleagues' and citizens' opinions on blockchain. Our vignette experiment is based on a hypothetical scenario related to the introduction of blockchain to create a digital identity for the provision of local public services. Using the influential classification of blockchain configurations Ølnes et al. (2017)., we distinguish four different options in blockchain configuration, according to two dimensions: more or less "Public Write" (who has permission to access to the network and input data into the blockchain: all users or just public officials), and more or less "Public Read" (who has permission to read information that lies within the blockchain: all users or just public officials). We find that, while the configuration regarding "Read" is non-significant, a more "Public Write" improves public officials' opinions both on their acceptance of blockchain and on its effects on trust in public administration and its services.

The rest of the article is organised into six sections. The second section includes a contextualization of blockchain in public administration and presents the research questions and the hypotheses based on them. The third section describes the experiment design and research method. The fourth section presents the results of the experiment. The fifth section discusses the main outcomes and empirical limitations. The sixth section concludes.

II. Blockchain in Public Administration

Blockchain configurations

Blockchain is not a given: there are multiple ways to configure a blockchain. An influential conceptual approach to the different possible configurations of blockchain has been provided by Ølnes et al. (2017). This is based on two key disjunctions: public/private and permissionless/permissioned. The public/private configuration of the blockchain determines who has access to the information that is inside the ledger. The permissionless/permissioned dimension determines who maintains the network and is involved in the consensus-making process (unknown independent nodes, if permissionless; authorised nodes, if permissioned), thus, the protocol to add new blocks of information to the ledger. Bitcoin and Ethereum are two typical examples of public permissionless blockchains. However, the use of permissionless infrastructures in public service provision is far from an obvious policy application (at least, at present):it is rather improbable that a public administration will opt to leave maintenance of the infrastructure of relevant public services to unknown nodes. Along with technical, operational and economic aspects, a permissioned blockchain facilitates compliance with data protection laws such as GDPR (Finck, 2018).

As regards the public/private dimension, this is not an extreme dichotomy, rather, a spectrum of different elements that can be used to position a blockchain on a point across these two axes. Blockchain can be configured in various ways giving different degrees of openness to citizen involvement and data transparency. To mobilise this, we use two particular elements that determine the openness of a blockchain: “Read” and “Write”. “Read” refers to who has permission to read information that lies within the ledger. “Write” refers to who has permission to access the network and input data into the blockchain. Table 1 relates these two concepts to our vignette experiment.

Table 3.1: Public/private configurations

Public/private mechanisms	*"Public Read"*	*"Private Read"*
"Public Write"	Citizens register and transact on their own and (non-personal) information is available to any user.	Citizens register and transact on their own but information is only available to authorised public officials.
"Private Write"	Individual registration process is validated by a public official, but (non-personal) information is available to any user.	Individual registration process is validated by a public official and (non-personal) information is only available to authorised public officials.

As seen in Table 3.1, a variety of configurations may lead to different permissions and responsibilities. On the one hand, the more public the "Read" mechanism, the more accessible the information. In contrast, a private "Read" mechanism would restrict the number of people able to access the information inside the blockchain. On the other hand, the more public the "Write" mechanism, the greater the number of users able to contribute to actions and transactions of the ledger. The more private the "Write" mechanism, the tighter is the control over who inputs into the ledger. This Read/Write classification will be applied and discussed in regard to our specific case, since the level of disruption to public administration (and subsequently, public officials' opinions regarding blockchain adoption) will depend on the specific configuration of each blockchain solution (Tan & Rodriguez Müller, 2020).

What Determines Public Officials' Opinions towards blockchain?

The introduction of new technologies has triggered profound organisational changes in public administration processes, particularly from the late 1990s onwards (Dunleavy et al., 2006). The spread of information technologies implies that changes no longer affect solely administrative processes, but the whole terms of relations between government agencies and civil society. At present, the spread of open government practices challenges siloed and hierarchical work models within public administration and drives new models based on transparency, public engagement, and co-production

(Altayar, 2018; Osborne, 2018). The adoption of "disruptive technologies" into public administration and the attitudes regarding the transformations they potentially create, justifies the need for an updated analysis.

Public officials' opinions about the implementation of blockchain can be contextualised as part of the larger literature on workers' resistance to change (Ajzen, 1991; Piderit, 2000; Dent & Goldberg, 1999). Additionally, this literature on workers resistance to change is complemented with insights from the more recent field of public sector innovation (Berry & Berry, 2014; Hartley, 2016; De Vries et al., 2016). A central idea from this latter body of literature is that individuals' cognition about the predicted outcomes of the innovation process has a profound effect on subsequent attitudes toward technology. Based on all of this literature, we identify a number of factors that may influence public officials' perceptions about blockchain adoption. These can be divided into factors associated with a more positive and with a more negative opinion on blockchain adoption. A summary of these factors is presented in Table 3.2.

1) Positive

Based on the literature, there are five major factors or conditions under which public officials are more likely to view blockchain positively. First, where public officials think that blockchain is going to improve public service delivery in terms of access to information, economic efficiency gains and inter-agency coordination (Baldwin, 2012). In this scenario, public officials believe blockchain is positive for society as a whole, since the quality and performance of services provided by public administrations would improve. Second, where public officials perceive that blockchain can reduce every-day human errors as a result of the automatization of administrative processes and saves time due to the reduction of paperwork. Third, where the innovation process goes along with

explicit top management support (Clohessy et al., 2018). Fourth, internal participation. Previous results show that involving employees through the dissemination of critical information and a system of feed-back communication creates a sense of ownership and reduces internal resistance (Fernandez & Rainey, 2017). This is particularly important in the public sector as public officials may be able to resist new initiatives until a new administration comes into power. Finally, organizational readiness, understood as the availability of technological and human resources (including both technical and organizational capabilities). Management and staff motivation, availability of resources and having the right staff attributes and the organizational climate to support the change are determinants of the success of innovations.

Public officials' views regarding their colleagues' attitudes are a critical factor in the success of innovation processes. Should public officials think their colleagues will resist change, despite their own efforts, innovation will be blocked or negatively impacted. Hence, it is also relevant to ask public officials about their views on their colleagues' opinions towards blockchain. There are three main motives which can result in a more favourable opinion regarding their colleagues' willingness to adopt blockchain. First, the introduction of blockchain is a further step in the automation of certain administrative processes which reduces paperwork and tedious day-to-day tasks. Second, blockchain technology could increase accountability in the provision of services. Third, public officials might consider that their colleagues will not understand the complexities of the technology but will voluntarily follow the instruction from top managers and the innovation department. The literature includes examples of successful innovation and change in public agencies taking into account diverse ecosystems (Arundel, 2017; Zhenbin et al., 2020).

Finally, citizens' attitudes are another crucial factor in innovation processes. Positive attitudes of citizens towards blockchain may positively influence those of public officials. However, public officials' and citizens' motivations and attitudes towards blockchain can differ. For this reason, we also test citizens' views (as perceived by public officials) on blockchain. Public officials might think most citizens will have a positive opinion about the introduction of blockchain based on the expected benefits of blockchain for citizens. The literature highlights three major benefits of blockchain for citizens. First, an improvement in the security of information contained in public administration servers. Second, greater control of personal data, and third, a higher level of transparency. Transparency refers to the availability and flow of timely, comprehensive, relevant, high-quality, and trustworthy information on government activities to the general public. Transparency thus refers to the extent to which the government makes data available to the public in order for them to evaluate government actions. Transparency is vital for establishing an ongoing basis for government accountability since citizens delegate decision-making authority. A public blockchain is transparent by design and, at the same time, it is able to assure the information included is not modified after its inclusion. Furthermore, positive citizens' opinions could be based on the idea that citizens appreciate a digital transformation of public administration that includes less human interaction and less public officials' discretion in administrative processes (Reddick, 2005).

2) Negative

Blockchain adoption can also lead to negative opinions from public officials. A public official may understand that blockchain applications will not improve public service delivery, if the benefits do not outweigh costs or, if the technology is still too

immature to offer tangible advantages in certain applications. However, even if public officials consider blockchain implementation as positive for the general interest, they could express negative opinions about it. Eight elements identified in the literature could motivate a negative opinion. First, people and organizations may tend to hold onto traditional ongoing practices, independent of how dysfunctional or illogical they may appear to others (De Vries & Balazs, 1999). In the case of blockchain, this effect increases, since blockchain implies many challenges in terms of technological infrastructure, professional and personal relationships (Papathanasiou, 2020). Second, public officials may consider that the introduction of a new technology challenges their current way of working and may mean their past work is subject to criticism. Third, public officials are generally risk-averse, which suggests they tend to resist change (including resistance to the introduction of a disruptive technology) (Buurman et al., 2012). Fourth, resistance to blockchain from public officials may be associated with fears about job security, and a potential decrease in income. This feeling would be stronger in the cases where the introduction of the technology is more likely to replace jobs. Fifth, public officials may perceive the introduction of blockchain as a further step towards opening up the work done by public administration to the public eye (Janssen et al., 2012), hence, some public officials may show negative attitudes towards it. Sixth, public officials may fear that an inappropriate disclosure of information due to blockchain technology could harm their job. Seventh, public officials' lack of experience, technical skills and/or knowledge to manage the technology can create resistance, as found in the case of private companies (Lember et al., 2019). Finally, change can represent a threat to current hierarchy inside the organization. The public officials that benefit from the status quo will probably oppose internal resistance to the adoption of blockchain.

Several reasons may lead public officials to think their colleagues might refuse blockchain. Potential reasons for rejection among colleagues will be similar to those previously described for public officials' own opinions. Among those reasons, key ones are threats to job security, loss of control from established responsibilities due to a higher involvement of citizens, and the tendency to hold onto current ways of working. However, even if a public official considers that the introduction of blockchain is positive for public service delivery, they may still perceive potential resistance from their peers. This line of thought is characterized by a pessimistic view of public bureaucracy, which has been traditionally stressed to be subject to dysfunction due to issues related to red tape, rigidity, and caution (Tullock, 1965). Public administration bureaucracy is often described as a rigid organization that fundamentally resists change (Osborne & Gaebler, 1992).

Finally, regarding citizens' opinion, public officials could think that citizens will hold negative views towards blockchain in public services due to a more general rejection of the digital transformation of public administrations. Blockchain can be viewed as another step in the further depersonalisation of the relationship between citizens and public officials (Kolsaker & Lee-Kelley, 2008). Moreover, the use of smart contracts in administrative processes further decreases the range of flexibility to adapt to distinct situations. In this respect, citizens could be also negatively affected by the potential reduction of human resources on public administrations as a consequence of the digitalization of processes.

Table 3.2: Motives for Public officials' opinions towards blockchain

	Positive	***Negative***
Own opinion	- Benefits for public service delivery -Improvements on own job -Top management support -Bottom-up participation -Readiness in terms of technical and organizational skills	- Economic costs and/or technical immatureness of the technology - Inertia towards existent work patterns -Fear of questioning past actions -Loss of job security - Negative attitudes towards the opening of public administrations to the public eye - Fear of inappropriate disclosure of information -Lack of technological experience and awareness -Changes in current hierarchy
Other public officials' opinion	-Reduction of paperwork and tedious workload -Diffusion of accountability	-Threat to job security - Loss of control -Tendency to hold onto traditional work patterns
Citizens' opinion	-Security of data -Control over personal data - Transparency - Less human interaction and less discretion in administrative processes	-Depersonalisation -Loss of flexibility - Negative consequences of the reduction of human resources on public administration

Hypotheses

To develop our hypotheses, we assume that the more public the configuration of blockchain, the more profound its disruption on organizational changes will be. Therefore, all the aspects discussed above will have a stronger effect in a case where a blockchain with a more public configuration is implemented than if a blockchain with a more private configuration is implemented. In particular, in our experiment, we probe whether different options in the configuration of blockchain impact public officials' opinions on: 1) Acceptance of blockchain; and 2) Trust in public administration and its services. We analyse public officials' opinions from three points of view: a) Their own opinion; b) their views on their colleagues' opinions; and c) their views regarding citizens' opinions.

As regards acceptance, a more public blockchain can enhance transparency as well as data security, be used to provide greater feedback, spark more agile administrative

processes, and make for less tedious tasks and ultimately, better public services (Janssen et al., 2012; Dawes, 2010; Wang & Lo, 2016). However, it can also cause a sense of loss of control among public officials. Reasons for this include the perception that a public blockchain may transform their current tasks and working hierarchies, make them feel more vulnerable as their work is made more accountable and demand a new set of skills (McDermott, 2010). In our hypotheses, we consider the possible configuration of blockchain within a spectrum between public and private, where the specific point will be determined by the two mechanisms previously described: "Read" (who has permission to read information that lies within the ledger) and "Write" (who has permission to access to the network and input data into the blockchain).

Hence, we formulate the following hypothesis:

Hypothesis 1A: When Blockchain is configured as more public, public officials are more likely to accept it.

Hypothesis 1B: When Blockchain is configured as more public, public officials are more likely to think other public officials will accept it.

Hypothesis 1C: When Blockchain is configured as more public, public officials are more likely to think citizens will accept it.

Trust in public administration is vital for good governance (Van de Walle and Migchelbrink, 2020). Potential changes in the level of trust in public administration resulting from blockchain technology can be analysed. A core element of blockchain is its potential to establish a new form of trust, due to its characteristics regarding immutability, transparency, and auditability which allows traceability (Shahaab et al., 2020). In this regard, the more public the blockchain introduced the greater is its

transparency (related with the "Read" mechanism) and control over personal data (related with the "Write" mechanism). However, the effect of both mechanisms on trust is not straightforward. Regarding transparency, the literature shows that the relationship between a more open public administration (including transparency and public engagement) and trust in public administration could be positive (Cucciniello & Nasi, 2014; Schmidthuber et al., 2021) but generally, it is more nuanced (Grimmelikhuijsen, 2012; Morgeson et al., 2011) or could even be negative (Moore, 2018; Grimmelikhuijsen et al., 2013). On the other hand, a positive relationship between user control over data and trust of the services should not be taken for granted (Lazaro & Metayer, 2015). We test these possibilities for the three actors we consider and formulate a second set of hypotheses:

Hypothesis 2A: When Blockchain is configured as more public, public officials are more likely to increase their trust in public administration and its services.

Hypothesis 2B: When Blockchain is configured as more public, public officials are more likely to think other public officials' trust in public administration and its services will increase.

Hypothesis 2C: When Blockchain is configured as more public, public officials are more likely to think citizens' trust in public administration and its services will increase.

III. Research Methods

Experimental Design

The hypotheses are tested using a vignette experiment. This method combines the internal validity of experiments with the external validity of surveys (Migchelbrink & Van de Walle, 2020). A vignette experiment consists of a survey-type exercise in which

participants are presented with a set of different vignettes and are requested to rate or react to each of them. Each vignette is slightly manipulated to include different features that are going to explain the rating variability. With this method, vignettes are able to test the causal impacts of those different features or variables (Jilke & Van Ryzin, 2017). Vignette experiments are useful to treat with the effect of beliefs, norms, opinions, or values on actual behaviour, especially those delicate or socially controversial opinions (Atzmüller & Steiner 2010).

The design of our vignette experiment includes two variables (factors), each of them containing two alternatives (levels). In this way, we present a 2 x 2 full-factorial design (Mee, 2009). The two factors we consider are two dimensions regarding possible blockchain configuration of "Read" (who has permission to see the information included in the system) and "Write" (who has permission to validate individual registration) mechanisms. Both elements of the blockchain can be presented either through a more or a less open configuration. As regards the "Read" factor, one level represents the situation of a more public or open "Read" configuration of blockchain ("Public Read": any resident with a digital identity can see the information included in the system), whilst the other represents a less public or open one ("Private Read": only council officials can do it). As regards the "Write" factor, one level represents a more public or open configuration of blockchain ("Public Write": the user can validate themselves in the registration processes), whilst the other represents a less public or open one ("Private Write": only a council official can do this). In order to prevent participants answering based on predefined opinions about blockchain, we do not name blockchain explicitly, although the description includes a reference to a decentralized technology. Moreover, we included a control vignette where neither of the factors are specified. This control vignette is useful to test the general opinion about the introduction of a technology with similar

characteristics to blockchain, without considering its specificities, in the provision of public services. Thus, each vignette included a specific combination of factors and levels that constitute five different vignettes (including the control vignette).

The vignettes were identically tested through a recurrent scenario in the realm of “Smart Cities”. Specifically, the vignette scenario considered a situation in which blockchain is introduced in the provision of a local Digital Identity. This scenario is not currently being discussed by policy makers in the context where the experiment is conducted. This is vital to avoid respondents' political ideology playing a major role in their answers, beyond their considerations about the concrete implementation of the technology. Hence, this scenario is appropriate when seeking to obtain conclusions about policy issues around the introduction of blockchain in public service provision, removed from more general political biases. The scenario described the situation of a fictional resident, who is going to use the service for the first time. The vignettes were administered to public officials in their own language. Figure 3.1 presents an English translation of the vignettes. The bold aspects represent the two factors and their two possible levels.

Imagine the following scenario:

The City Council where you work is considering introducing a "Digital Citizen Card". We will ask you a series of questions regarding your opinion on the matter. To do so, consider the case of Juan, a fictitious citizen living in Santander.

Juan, as a user of the "Digital Citizen Card", will be able to digitally store personal information (ID card, date of birth, address, etc.), and share it in case he needs it. Juan's personal data will be stored in a way that guarantees his anonymity. This personal data will be stored in a decentralised manner (i.e. on several servers simultaneously), which increases the security of the information, and ensures that it cannot be modified without his consent.

The "Digital Citizen Card" will be used to facilitate access to services such as bicycle rental, sports facilities, libraries, cultural events, urban transport and parking, among others. Thanks to the "Digital Citizen Card", municipal services will be integrated into the same platform, which will streamline administrative processes and allow residents like Juan to access these services.

To obtain the "Digital Citizen Card", Juan has to download the application on his mobile phone. His registration in the application has to be validated online (without being physically present) **by a council official/by the user** before he can start using it. After registration, **Juan and all residents of the municipality using the "Digital Citizen Card"/council officials** will be able to access global statistics about the total number of citizens and the frequency with which they use each of the municipal services.

Figure 3.1: The vignette

After the vignette was presented, we asked respondents to express their opinions on two main questions. Firstly, as regards acceptance of blockchain technology, we asked public officials whether the technology should be adopted ("The local council should use this "Digital Identity App" to deliver public services"). Secondly, as regards the effects of blockchain on trust, we asked public officials whether a potential adoption of this technology would influence trust ("This "Digital Identity App" will increase trust in public administration and its services"). Along with their own opinions ("According to you"), we asked public officials about their views of their colleagues' opinions ("According to what you think the majority of public officials in the Council will say"), and about their views on citizens' opinions ("According to what you think the majority of citizens in Santander will say"). To sum up, we estimated the effects of different options in the configuration of blockchain (as regards the "Read" and "Write" mechanisms) on six different outcome variables (two dimensions -acceptance and trust-, and three points of view -own opinion, colleagues' opinion and citizens' opinion-). All

six variables were asked to be rated on a 7-point Likert-like scale (1=strongly disagree, 7= totally agree).

In the experiment, the vignettes were assigned using a within-subjects design, in which each public official responded to two randomly assigned vignettes.

Sampling

The sample included all the public officials of the City of Santander, a medium-sized city in the north of Spain, with a population of around 180.000 inhabitants. Santander is known to be one of the cities that have made the greatest commitment to innovation within the framework of "Smart Cities" with the aim of improving the efficiency and quality of municipal public services (Sanchez et al., 2014). The sample contains the whole workforce of public officials of the city council (N=1038), given that the introduction of a technology such as blockchain potentially concerns not only those public officials in charge of making policy, but also those street-level public officials whose everyday work would be affected by a new way of managing the local services. We administered the survey online, through the specialized program Qualtrics. Every public official received an email with the information about the survey and its objectives. We sent a reminder email one week prior to the closure of the vignette experiment. The survey took around 15 minutes to complete.

Fielding

The vignette experiment was launched on 20 January and closed on 12 February 2021. Of the 1,038 individuals of the population, 330 answered the invitation to participate and 149 individuals completed the whole survey. Using Pearson’s chi-square tests, no significant differences on background characteristics (gender, age, professional rank and self-perceived technological skills) were found between dropouts and the final

sample of respondents. Our sample includes 64% of women and 36% of men. The age of the majority of respondents is between 40 and 60 years (74%) while 17% of them are below 40 and 9% are over 60. Regarding administrative rank, 41% of the respondents have a position which requires a university degree (rank A) and 28% of them have a position that requires higher secondary education (rank C1) or lower secondary education (C2). Finally, respondents' rate of their own technological skills is good or very good (55%), good (39%) or poor or very poor (6%). Comparing the characteristics of the sample of respondents and the sampled population of public officials of the city council, our sample overrepresented women (64% in our sample, 34% in the population) and public officials in positions which require a university degree (41% and 25%, respectively). This reflects the challenge of this kind of experiment (conducted online) to reach those workers who have less daily contact with email (for instance, the police and firemen departments, where the majority of workforce are men and occupy positions which do not require a university degree). We assessed the randomization of vignette combinations using four balance tests. Specifically, four chi-square tests of vignettes independence were performed to confirm there were no statistical differences in the parameters of the overall sample compared with the individual vignette samples of respondents ($p>0.05$).

Method of analysis

To examine the results of the experiment, we conduct three separate exercises. First, we show the distribution of the outcome variables to assess the general opinion toward blockchain (jointly considering all possible vignette combinations). Second, we display the vignette means and standard errors for the outcome variables, separately for each possible vignette combination. This shows a visual representation of public officials' opinions based on outcome means depending on the combination of factors and levels

which represent variations in blockchain mechanisms of "Read" and "Write". Third, we estimate the average treatment effects (ATEs) of "Read" and "Write" mechanisms following Mee's 2 x 2 factorial design model (Mee, 2009). To this end, we transform the variables into two orthogonal factors that take the code of 1 when the mechanism is "public" ("Public Read" and "Public Write", respectively) and -1 when it is not ("Private Read" and "Private Write", respectively). For this exercise, the control vignette is excluded, resulting in a total of 230 individual vignettes. In order to account for the within-subjects design, we estimate confidence intervals using cluster-robust standard errors at the individual level (Hainmueller et al., 2014).

IV. Results

Figure 3.2 displays the density plots of the answers for each of the six outcome variables: on acceptance (above) and on trust (below), for respondents' own opinions, their views on their colleagues' opinions and their views on citizens' opinions. Regarding the acceptance of the technology, 71.8% of respondents either moderately agree (6) or strongly agree (7) with the introduction of blockchain to provide a local digital identity (own opinion). The percentage decreases to 43.3% and 40.3% who moderately or strongly agree when asked about their views on their colleagues' opinions and citizens' opinions, respectively. As regards the effects of blockchain on increasing trust in public administration and its services, 39.9% of respondents they moderately agree (6) or strongly agree (7) (own opinion), and 31.5% and 30.2% either moderately or strongly agree when asked about their views on their colleagues' opinions and citizens' opinions, respectively.

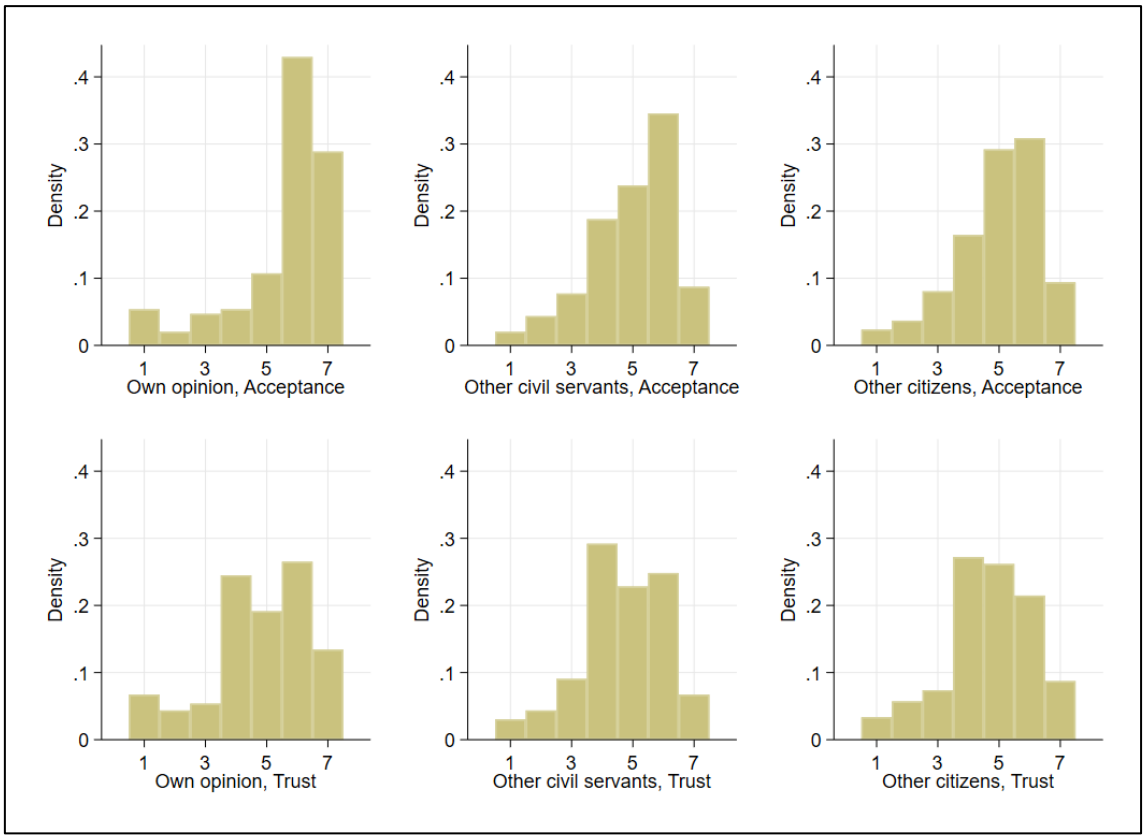

Figure 3.2: Density plots for each dependent variable

The previous figures can be compared across different socio-economical groups. First, there is no significant difference between women's and men's average scores. Second, differences across age groups are almost negligible. Third, respondents' rank positions do not have any clear correlation with views on blockchain adoption or blockchain effects on trust. Fourth, there is a strong correlation between self-perceived technological skills and more positive views of blockchain.

Figure 3.3 shows the mean and standard deviation of public officials' responses for each outcome variable, for each vignette combination of factors and levels. Regarding public officials' opinions on the acceptance of blockchain, the combinations that include "Public Write" are the ones with the highest mean scores. This is also observed regarding public officials' opinions on the effect of blockchain on trust in public administration and

its services (except for their views on citizens' opinions). These results suggest a preference of public officials towards a "Public Write" option in blockchain configuration, instead of a "Private Write" option. Figure 3 shows also that the average scores for the control vignette are similar to those for the combinations that include "Public Write".

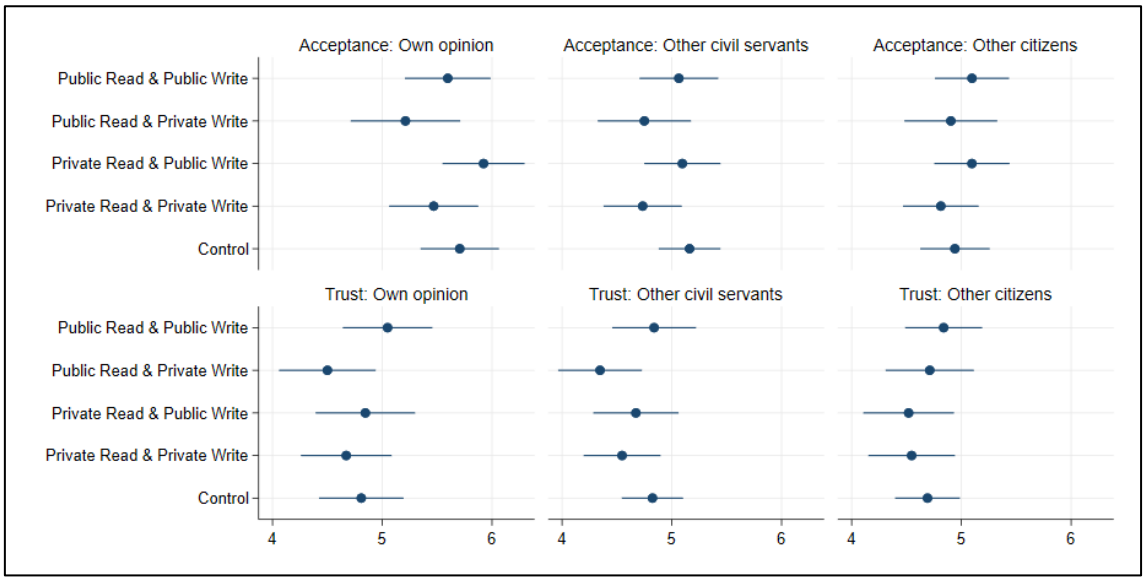

Figure 3.3: Mean and standard deviation by combination of configurations

Next, Table 3.4 presents the estimated Average Treatment Effect (ATEs) of "Read" and "Write" options in blockchain configuration on public officials' opinions on the introduction of blockchain. On the one hand, a "Public Write" configuration of blockchain (all users, not only council officials, can validate the registration process) has a positive effect on public officials' own opinions on both acceptance of blockchain and on blockchain effects on trust in public administration and its services. The same result is observed for public officials' views on their colleagues' opinions, both for blockchain acceptance and for blockchain effects on trust. In other words, public officials think that a "Public Write" configuration of blockchain is preferred by themselves, and also by their colleagues. In contrast, there is not a significant effect of a "Public Write" configuration of blockchain on public officials' views on citizens' opinion, neither for acceptance nor

for trust. On the other hand, a "Public Read" configuration of blockchain (all residents with a digital identity and not just council officials, can see the information included in the system) has non-significant effects on any of the six outcomes considered (acceptance and trust, public officials' own opinion and their views on their colleagues' and citizens' opinions).

Table 3.3: ATEs of Public Read and Public Write

	Own opinion (accept)	Colleagues (accept)	Citizens (accept)	Own opinion (trust)	Colleagues (trust)	Citizens (trust)
Public Read	-0.146	-0.004	0.023	0.008	-0.009	0.121
	(0.107)	(0.091)	(0.090)	(0.103)	(0.088)	(0.092)
Public Write	0.210*	0.169*	0.119	0.181*	0.155*	0.025
	(0.094)	(0.082)	(0.081)	(0.089)	(0.078)	(0.076)
Pub.Read*Pub.Write	-0.017	-0.012	-0.023	0.093	0.092	0.039
	(0.090)	(0.084)	(0.080)	(0.099)	(0.089)	(0.093)
Constant	5.550*	4.911*	4.977*	4.767*	4.601*	4.654*
	(0.131)	(0.118)	(0.115)	(0.140)	(0.122)	(0.129)
Observations	230	230	230	230	230	230
Adjusted R^2	0.010	0.001	-0.005	0.002	0.002	-0.005
F	2.119	1.501	0.867	1.791	1.595	0.735

Standard errors in parentheses
* $p < 0.05$

V. Discussion and limitations

Our results show that a blockchain that includes "Public Write" mechanisms (all users can validate the system's registration processes) has a higher degree of acceptance by public officials than a blockchain including "Private Write" mechanisms (only council officials can do this). A perceived improvement in service quality, greater efficiency in service provision, and the fact that there is a reduction in daily work and thus a reduction in the tasks public officials must do, may be arguments for such visions (Baldwin, 2012). In addition, this result shows that public officials in our experiment consider that the perceived benefits described above overshadow the potential risks that may arise when the provision of the public services is configured in a "Public Write" setting. Thus, evidence of a fear of the automation of certain processes and the replacement of human

supervision by technological supervision among public officials does not prevail in our experiment. Alternatively, even if this fear exists, it does not overshadow the perceived benefits in the case of blockchain acceptance (Meijer, 2015). In terms of the effects of blockchain on trust, the shift of responsibility from public officials to citizens is not viewed by public officials as a point of instability but as a positive point for service provision (Linders, 2012). The key reasons for this opinion could be the confidence in blockchain's properties (immutability, transparency, and auditability) and the ability to track every piece of information.

In contrast, a more "Public Read" mechanism (any user can see the information included in the system) does not present a significant effect on public officials' acceptance or trust in public administration and its services, with respect to "Private Read" (only council officials can do it). There are several reasons that play for and against increasing transparency in the administration of public services from the point of view of public officials (Janssen et al., 2012). On the one hand, it has been noted how transparency can contribute to improving legitimacy and trust in public administrations through greater levels of accountability, improving public services and stimulating economic and social innovation (Harrison et al. 2012). In addition, public officials may benefit from feedback, now possible based on the fact citizens have access to more data about public services. On the other hand, public officials may feel their personal rights are infringed upon by publishing the administrative data (Wirtz et al., 2016). Moreover, public officials may think that data that could lead to greater criticism of the public administration and, therefore, should not be made available to general users. Our results indicate that none of the possible reasons is of any defining importance, or that positive and negative points counteract each other.

Interestingly, we also found that public officials' own opinions coincide to a large extent with their views on their colleagues' opinions on how blockchain configuration affects both blockchain acceptance and blockchain effects on trust. These results show that public officials consider that their co-workers generally share with them a common set of opinions and interests as regards the motivation in favour and against the introduction of blockchain technology in public service provision. In contrast, this is not the case for public officials' views on citizens' opinions: citizens are perceived to have different motivations and attitudes. City council public officials do not find a defining effect of a more public configuration of blockchain (neither "Public Write" nor "Public Read") on citizens' opinions. This may be because the advantages and disadvantages for citizens of a service with a higher degree of digitalisation cancel each other out (Hupe & Hill, 2007), or result from the idea that the changes introduced by the technology will not generate strong attitudes among citizens.

The study presents some limitations, which need to be considered in order to interpret its results and to generalize them to other settings. First, it is important to consider that the way in which the survey was provided to the city council workers (via email) presented more difficulties for reaching public officials with less frequent daily access to email. Thus, the survey over-represents women and public officials in positions which require a university degree. The results may be influenced by particular attitudes of public officials within these groups. Second, the scenario is based on the introduction of blockchain for providing a local digital identity. The results may change if other scenarios are considered due to differences between various applications of blockchain, for example, in terms of accountability, need for control, privacy or usefulness of public data. Third, Santander is a city with years of experience in the field of innovation and the introduction of new technologies to provide local services. Local public officials may

have a more favourable starting opinion compared to those in other places with a different background and, specifically, a more favourable opinion on certain configurations of blockchain. Fourth, the majority of public officials in Spain, including those at the municipal level, face a hard and long process to obtain their jobs, but once attained, these jobs are very stable. The shift of responsibilities from public officials to citizens may result in a more reluctant view towards blockchain in other contexts where the risk of losing one´s job is greater. Given these limitations, further research is needed to confirm and complement the insights found in this study.

VI. Conclusions

Recent developments in blockchain make it an attractive option for application in a wide range of sectors within public administration, since it potentially has the capacity to improve the provision and quality of many public services. However, it should be borne in mind that it is not a one-size-fits-all technology: blockchain can be adapted to the needs and interests of each application, taking advantage of the flexibility in its configuration. A more public configuration of blockchain (in terms of the permission to access to the network and to input data into the ledger) may increase public officials' acceptance of, and trust in, the introduction of blockchain in public administration. However, this effect may differ depending on the context and specific setting. For this reason, careful evaluation ex-ante and also ex-post is required.

In this paper. we conducted a vignette experiment to analyse public officials' opinions on different options in the configuration of blockchain introduced for the provision of a local digital identity. The experiment was conducted in the city of Santander, Spain, and addressed public officials' views on the impact of different blockchain configurations on the acceptance of the technology and its effects on trust in

public administration and its services. Unlike a survey, the use of a vignette experiment allows us to extract causal effects from a combination of variables.

The main contributions of the paper are twofold. First, from an academic perspective, the experiment applies an innovative methodology to an emerging field; the implementation of blockchain into public services. The paper establishes a classification of the technology based on its main mechanisms from a policy point of view which helps to focus some of the determinants of its adoption. Hence, it shows the usefulness of vignette experiments to evaluate innovation processes in public administration. Second, the paper draws some public policy implications regarding the attitudes of public officials towards the adoption of a technology that is essentially decentralised, such as blockchain. The results of the experiment show that, in aggregate, public officials positively value the decentralisation of some bureaucratic processes, which can be delegated to citizens through the use of the decentralised technology. At the same time, public officials do not value as highly the transparency that a decentralised technology such as blockchain can offer for the management of public services and information. The careful consideration of these two aspects could be central to assure a successful application of a blockchain in a public service.

Chapter 4. Blockchain in Government: Towards an Evaluation Framework

I. Introduction

Distributed Ledger Technology (DLT) has recently gained significant attention and investment in various industries, including government. In fact, DLT is considered, at present, one of the technologies with the greatest potential for disruption in public administration (Cagigas et al. 2022). DLT, commonly used as a synonym of blockchain, is a decentralized database that enables secure and transparent sharing of information among multiple parties by relying on a shared ledger that is distributed among all peers in the network. This ledger is made up of a series of blocks that contain new data, as well as an identifier (a hash) of all the information introduced in the previous blocks of the chain. Each time data is added to the blockchain (Kassen, 2022), it is written to a new block, which is then sealed and becomes a permanent part of the chain. This process continues indefinitely, with new blocks being added to the chain in a strictly sequential manner. This allows any peer on the network to easily verify the information contained in any block on the chain, making it difficult to manipulate the data stored on the blockchain.

DLT has the potential to streamline processes, reduce costs, and increase trust and accountability in government operations. Potential benefits of DLT in government include increased efficiency, transparency, and security in various processes such as voting, procurement, and citizen services (Cagigas et al., 2021). For example, DLT can enable secure and transparent voting systems, reducing the risk of fraudulent activities and increasing voter confidence. It can also enable the efficient and transparent tracking of procurement processes, reducing the potential for corruption and increasing accountability. However, the hype surrounding DLT has sometimes led to exaggerated

expectations - and the introduction of this technology is not exempt of significant challenges. Potential costs and risks associated with the implementation of DLT in government include the high initial investment and technical expertise required, as well as potential issues related to scalability and interoperability. Moreover, DLT may introduce a significant cost derived from its high energy consumption, which may result problematic in terms of environmental concerns (Gabison, 2016). Additionally, DLT can potentially displace existing workers and disrupt established practices and systems. Benefits, costs and risks of the introduction of DLT in government may vary depending on the sector and the stakeholder considered, and might comprehend a broad range of multiple issues, including technological, socio-economic, organisational, legal and political factors. It is therefore crucial to correctly evaluate and measure the effects of the introduction of DLT in government (Allessie et al, 2019), in a perspective capable of incorporating these multiple factors.

This paper provides an evaluation framework to analyse and compare the benefits and the costs and risks of the introduction of DLT in specific use cases within the public sector. Built from a systematic review of the literature and ex ante semi structured interviews with public servants involved in future DLT pilots, it first identifies a comprehensive list of factors representing potential benefits, costs and risks of the introduction of DLT in government in four separate dimensions: technological, socio-economic, organisational-cultural, and institutional (legal and political). For each of these factors, the evaluation framework identifies an evaluation question and defines a metric able to measure it (Key Performance Indicators, KPI). The use of this set of KPIs allow to measure, analyse and compare the information on the benefits, costs and risks of the introduction of DLT in government in a multi-dimensional perspective while, at the same time, simplifying the understanding of the innovation process. This evaluation framework can be used by

researchers, policy makers, and practitioners to assess and compare the impact of the introduction of DLT in single use cases, within specific government contexts.

The rest of this paper is structured as follows. The second section addresses the policy problem around the need of evaluating the introduction of DLT in the public sector. The third section discusses the main factors, representing potential benefits, costs and risks of the introduction of DLT in government, from which the evaluation framework is built upon. The fourth section presents the evaluation framework. The fifth section concludes.

II. The policy problem: evaluating the effects of DLT in the public sector

The lack of real evidence on the effects of DLT in the public sector, in a multidimensional perspective which comprehends all the potential benefits, costs and risks of DLT, is a significant concern for policymakers who aim to promote the introduction of this technology in the public sector. DLT has the potential to revolutionize many aspects of the government, including the way that governments and public organizations manage and share data, conduct transactions, and engage with citizens (Ølnes et al., 2017; Datta, 2021). However, without clear and complete evidence on the multiple effects that the introduction of DLT may have on a specific context within the public sector, it is difficult for policymakers to make informed decisions about whether and how to adopt this technology.

There has been a growing recognition among policymakers that it is important to develop more robust evidence on the effects of DLT in the public sector. To address this policy problem, public institutions around the world have been investing in research and development to increase our understanding of the potential uses and impacts of DLT. This includes funding research studies and pilot projects to test the effectiveness of this technology in different contexts and sharing the results of these studies with policymakers

and other stakeholders. Even though these pilot projects are essential to increase knowledge of the innovation process, they often present a number of challenges that complicate the extraction of definitive insights.

One of the main challenges with DLT is that they are relatively new technologies, and there is still a lack of understanding about their potential uses and impacts. This lack of understanding is compounded by the fact that DLT is complex and technically challenging, which can make it difficult for policymakers to evaluate their potential effects. Additionally, the use of this technology is often subject to political and regulatory constraints and uncertainties, which can make it difficult to conduct rigorous studies on its effects (Amend et al., 2021).

Another challenge is that the evidence on the effects of DLT in the public sector is often fragmented and inconsistent. This is because there are many different applications of this technology, and the effects of each application can vary depending on the specific context in which it is used. The evidence on the effects of DLT is often based on case studies or pilot projects, which can be limited in scope and may not be representative of the broader public sector (Lindman et al., 2020). While the effects of DLT in the public sector may commonly be case-specific, there is a need of a homogeneous framework in which the evaluation of these effects can be done and compared across different cases. A final challenge is that new technologies often create dependencies from technology and other service providers.

In order to limit these challenges, the use of standardized frameworks and metrics to evaluate the effects of DLT in government should be encouraged. A framework for evaluating the introduction of DLT in the public sector needs to be consistent and comparable across different contexts while, at the same time, it should be flexible: tailored

to the needs and information availability in each specific case. This can help to build a more comprehensive evidence base on the effects of this technology and can also facilitate the development of best practices for their use in the public sector.

III. The potential benefits, costs and risks of DLT in the public sector: an Assessment Framework based on insights from the literature

The evaluation of the introduction of DLT in the public sector requires a framework that captures a number of factors, across multiple dimensions, that play a role in the innovation process. On this basis, we design an Assessment Framework to encompass and analyse the different factors representing potential benefits, costs and risks of the use of DLT in the public sector, classified into four dimensions: Technological, Socio-Economic, Organisational-Cultural, and Institutional. This exercise achieves two objectives. First, the Assessment Framework can be used as a general guide when DLT is considered for implementation in most public services and an assessment is required. Second, the Assessment Framework provides a common, shared multidisciplinary approach from which a more detailed Evaluation Framework can be developed. This approach captures the multidimensional perspectives to be considered at the "high" level and establishes the conceptual relations between them.

Figure 4.1 summarizes our Assessment Framework for evaluating the introduction of DLT in specific cases within the public sector. On the left of the framework is the "critical variable" for assessment, the technology, which is being introduced to the public sector, and the public services affected. In the middle, we find the "conditions" affecting the introduction of the technology, which are organised into three categories: socio-economic; organisational-cultural; and institutional (legal and political). The socio-economic dimension captures the public sector in society and its economy at large, as

well as considering its main stakeholders: citizens, firms and the third sector. The organisational-cultural dimension captures elements internal to the public sector as an organisation, including work practices within government and civil servant attitudes. The institutional dimension captures elements associated with the legal, regulatory, and political structures at different levels, including the local, national and international levels, where applicable.

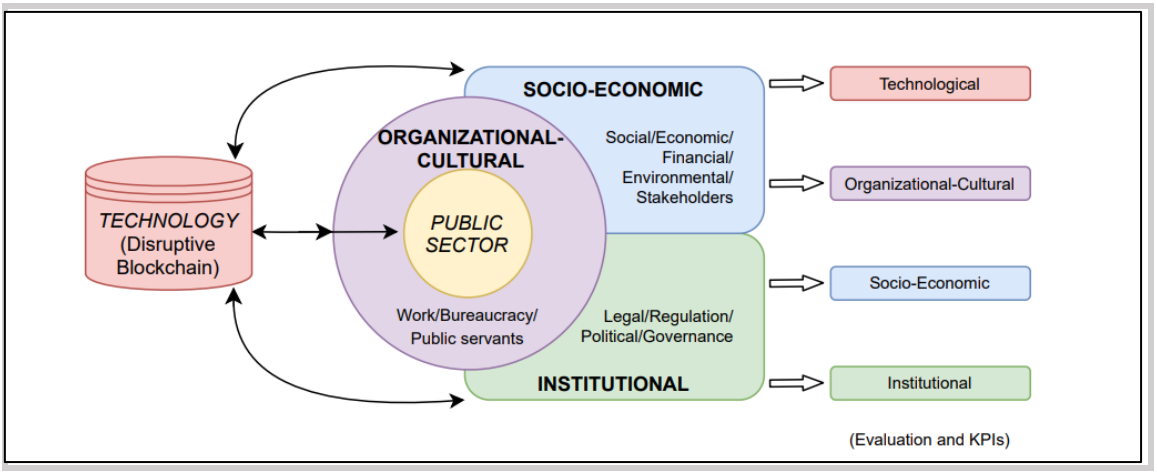

Figure 4.1: The Assessment Framework for evaluating the introduction of DLT in the public sector

This Assessment Framework brings together the main factors representing potential benefits, costs and risks of the implementation of DLT in the public sector, and organizes them around the four dimensions previously introduced. These factors are identified from a systematic review of the literature and from ex ante semi structured interviews with public servants involved in future DLT pilots.

Technological

The most relevant technical factors identified as regards this dimension are the following:

- *Unified system standards*: DLT promises to harmonise technical requirements for the gathering and aggregation of public data. However, the lack of initial technical and regulatory standardisation has hampered the communication

between different networks and their scalability (Allen et al., 2019). This is a critical issue to solve, because instead of a single ledger (such as the case of the internet), there could emerge multiple public and private platforms that would require some level of interoperability.

- *Aggregation of data ledgers*: Separate databases or sets of data files called "data silos" can stifle productivity by preventing public officials from getting a "360-degree" view of all data. This can result in service disruptions or poor data-driven decisions. DLT could allow for the concentration of larger portions of information constructing more complete datasets of public data. These large pools of data could be used to guide public policy and enhance efficacy and efficiency of public services.
- *Automation of processes*: Tasks conducted by civil servants may also benefit from the reduction of every-day human errors resulting from the automated means of storing data provided by DLT (Allessie, 2019). Once DLT is introduced, the tasks of civil servants in certain public services would change, and focus on developing, maintaining and governing the DLT application (Ølnes et al., 2017).
- *Data integrity*: Immutability means that DLTs are based on an append-only data structure. DLT verifies every transaction through a consensus mechanism between nodes ensuring no single party has the unique power to alter it. As soon as a new block of data is verified and introduced in the chain, it is almost impossible to modify. While this is an attractive feature in many government contexts, there may be others where the difficulty of correcting human error is not a desirable feature.

- *Decentralisation*: DLT is not vulnerable to single availability breaches because data is not stored centrally. Furthermore, each node develops the process in a transparent and accountable manner (Myeong & Jung, 2019). As a result, from a technological standpoint, cybersecurity would be a major benefit for citizens in countries that adopt DLT technology.
- *Disintermediation*: The trust built on a secure and transparent distributed ledger removes the need to hire, pay, and rely on a third-party entity to oversee transactions. Payment networks and money transfer services in the public administration systems are all examples of financial intermediaries that could be drastically reduced. Furthermore, smart contracts can organise simple financial arrangements, ensuring that everyone follows the agreement.
- *Traceability*: The ability to identify and track the information and events associated with a product or service is referred to as traceability. Due to the immutability of the registry, DLTs allow for a complete traceability of transactions from the first-time information was input. Location, application, manufacturing characteristics, and environmental issues are just some of the characteristics and attributes associated with a product that can be traceable. Other benefits of traceability for the government could include authenticity, safety, and accountability across various sectors (Iftekhar & Cui, 2021). Aside from other characteristics, each record of product data could also include information about the labour conditions that were used during production. As a result, traceability could aid in the promotion of better human rights and fair labour practices.

Socio-Economic

The main socio-economic factors identified as regards this dimension are the following:

- *Financial efficiency*: The introduction of DLT into public services benefits governments by heralding new ways of storing and sharing information that may improve processes. DLT proposes an automated means of storing data in a tamper-evident, secure digital format instead of lengthy, bureaucratic procedures, resulting in potential reduction of costs.
- *Public value*: A high capital input is a requirement to introduce a DLT system for the first time. Previous research on the availability of DLT in local applications has concluded that the current technological cost of switching to DLT may not outweigh the added security it provides (Gabison, 2016). A correct assessment of the public money invested in each specific case is needed in order to conduct a credible cost-benefit analysis.
- *Time efficiency*: DLT has the potential to drastically reduce the amount of human effort required to run processes in many public services, resulting in time savings. Additionally, this implies a decrease in common human errors (Allessie, 2019). As a result, DLT has the potential to transform and improve the time efficiency of all public services that involve managing large sets of records and sharing information (both internally and externally) with citizens, businesses, and other sectors.
- *Environmental impact*: The development of DLT poses a significant cost in terms of its high energy consumption which depends heavily on the specific consensus mechanism in place. Overall, converting recording systems to DLT and scaling them to the scale required to serve large populations could be costly and environmentally damaging.
- *Social and geographical inclusion and participation*: The usability of DLT technology remains a major roadblock to widespread adoption. Not only

governmental bodies but also several social groups may be unable to immediately benefit from new technological applications due to a lack of knowledge and technical skills. Before it is released to the general public, it may be critical to improve user-friendly DLT interfaces and ensure some level of DLT literacy.

Organisational-Cultural

The most relevant organisational-cultural factors identified are the following:

- *Government culture*: DLT technology may allow the public to easily monitor the activity. This exposure of relevant information could result in a reduction of non-desirable behaviour within the governments regarding administrative procedures. DLT are per se designed for transparency and public monitoring, whereas the public sector often has a hierarchical decision structure, which may hinder to exploit the full potential of the new technology.
- *Reduction of bureaucracy*: The use of DLT in government services may reduce the need for paperwork and bureaucratic intervention in administrative processes. For example, Bhatia & Wright de Hernandez (2019) highlight the potential of DLT to reduce the amount of paperwork required to verify credentials in the field of records management. Chang et al. (2019) discusses the potential for DLT to reduce the amount of paperwork and interventions required for international trade. The organisational transformation may also lead to a reduction of common human errors brought on by the automated data storage. However, internal resistance to change and the risks associated with it may also arise in an organisation, constituting a significant barrier for the introduction of DLT
- *Agency coordination*: The increasing possibility for coordination is another significant organisational factor identified in the literature. On the one hand, DLT

has the potential to improve inter-agency coordination. A government DLT proposal could include a shared ledger of administrative documents that any accredited civil servant could view and extract information from. On the other hand, the use of DLT technology could improve communication and coordination between civil servants and other key players in the delivery of public services. In the field of healthcare, for example, DLT could improve direct communication between physicians and pharmaceutical companies, as well as between physicians and their patients.

- *Transparency*: Although a single-node, centralised system could be transparent, DLT transparency is based on trust, as no transaction can be manipulated after it is recorded. The rebalancing of power in every transaction where information asymmetry is evident may constitute a benefit of DLT for citizens (Centobelli et al., 2022). Furthermore, in a citizen-to-citizen transaction, it becomes very easy to verify whether one network participant has an exact and unmodified copy of the historical data stream.
- *Organisational learning*: The lack of necessary skills among civil servants is identified by the literature as a major risk of the introduction of DLT. Because DLT is a complex technology, DLT literacy may be a challenge not only for citizens who use the services, but also for civil servants. As a result, government agencies would need to train and hire technical experts in order to develop DLT applications. In addition to professional coders, the public system would need to employ a wide body of lawyers who should be familiar with digital law and disruptive technologies (De Filippi et al. 2022).
- *Ownership and technology control*: DLT is still a complex technology that requires specialised knowledge for creation and management. A minority of

experts dictates the rules of the system and how it is governed: this constitutes an additional risk for citizens and governments. Only a few individuals can modify the code, and there is a risk that the design of the system will represent their interests (Ølnes et al., 2017). Therefore, they could hold dominating powers, diminishing the capacity to integrate enough checks and balances into the DLT network.

- *Civil servants' attitudes*: As in the cases of other disruptive technologies, such as artificial intelligence and robotization (Clifton et al., 2020), successful DLT adoption requires workers' acceptance of the technology. However, literature shows that acceptance depends on a range of contextual factors (Cagigas et al, 2022; Janssen et al., 2020). Public officials' opinions about the implementation of DLT can be contextualised as part of the larger literature on workers' resistance to change, which has found that people's perceptions of the outcomes of the innovation process have a significant impact on subsequent attitudes toward technology.

Institutional

The main institutional (legal and political) factors identified are the following:

- *Legal compliance*: the disruptive properties of DLT data might be legally problematic with respect to current laws. For example, the fact that no one can easily delete certain information due to the immutability of DLT might conflict with several European Union laws such as the 1995 Directive or the GDPR (Han & Park, 2022). This is the case of the right to be forgotten for personal data. Furthermore, it is still unclear what kind of legal recognition will receive the data in the DLT, and whether (and which) additional conditions will be required for it

to be recognised as legal. Similarly, how to deal with inconsistencies between DLT contracts and court decisions or legitimacy disputes between DLT and physical parallel systems would need to be determined.

- *Privacy*: Although encryption and pseudonymization helps to protect DLT users' privacy, the risk of re-identification exists. Despite the fact that each user in DLT is associated with a public pseudonymous address, the transactions could be open to the public, and all network participants would see the information. A growing body of evidence suggests that using transaction details to de-anonymize individuals is possible (Liang & Ju, 2022). However, the more transparent the DLT is, the bigger the risk of re-identification.
- *System security compliance*: Though security is a major benefit DLT may bring, it also poses a crucial risk, according to the literature: the possibility that "private keys" of the DLT system are stolen, or that other potential malicious and coordinated attacks are made to the network. When other consensus mechanisms are adopted instead of "proof-of-work", as a way to reduce energy and computational needs, the security of the network may get affected since these alternative consensus rules are less strict. Additionally, hackers could take advantage of breaking points caused by poor coding. Finally, if the underlying cryptographic algorithms are broken while the DLT is still in use and cannot be replaced or decommissioned in due time, the security advantage of the technology is lost, and this systemic risk is worth being monitored during the lifetime.
- *Trust by design*: DLT is not a substitute for institutional trust and institutional infrastructure (Brookbanks & Parry, 2022). In fact, the creation and maintenance of the technological systems in which DLT is based ultimately rely on institutions

either through direct management or through externalised services. Countries with higher degrees of good quality public and civil services adopt DLT earlier and more successfully (Reddick et al., 2019).

- *Citizen participation*: the use of DLT for applications such as e-voting, access to public registries or citizens' cards could represent an opportunity to enhance citizen involvement and co-production of public services (Mačiulienė & Skaržauskienė, 2021). However, this effect cannot be taken for granted. Citizens might be reluctant to use the technology based on lack of information as well as lack of specific skills required.

IV. An Evaluation Framework for the introduction of DLT in the public sector

The Evaluation Framework (Table 4.1) is based on the Assessment Framework described in the previous section. This Evaluation Framework has been tested in four pilot use cases, representing pioneering cases in the introduction of DLT in government across four EU municipalities .

The Assessment Framework defined all the main factors, representing potential benefits, costs and risks of the introduction of DLT in the public sector, identified by the literature in the four dimensions considered (Technological, Socio-Economic, Organisational-Cultural and Institutional -Legal and Political-). For each of these factors, the Evaluation Framework deploys an evaluation question, which addresses a specific query on whether the potential benefit, cost or risk in question has taken place as a result of the introduction of DLT. Then, each evaluation question is shaped into a KPI, which is a specific indicator addressed at evaluating that evaluation question in particular. The evaluation questions and the KPIs can be tailored in each use case to its specific

circumstances, while attaining comparability. That means that, for each use case, the research question can be interpreted in the way it fits with each case's specific context, and the KPI can be adapted in accordance with the characteristics, the needs and the availability of information in each case. The whole set of values obtained for the KPIs serves to evaluate, in a multi-dimensional perspective, the impact of the introduction of DLT, in a specific use case, and to compare it with other use cases within the public sector context.

Table 4.1: Evaluation Framework for use cases on the introduction of DLT in the public sector

DIMENSION	**Potential Benefits/Opportunities**	**Potential Costs/Risks**	**Evaluation Question**	**KPI**	**KPI value**
Technological					
Socio-Economic					
Organisational-Cultural					
Institutional (Legal and Political)					

Before going on to describe each of the KPIs, it is important to note that the paper intentionally avoids the provision of a specific benchmark level for each of the KPIs but indications on their construction. This was a deliberate decision made to ensure results are valid and useful, as each implementation case may well present different measures as well as criteria for what constitutes a positive or negative result. It is up to the reader to establish their own normalization and comparability methods as per their specific requirements. The ISO 27004 standard, which provides guidance on how to create and use performance indicators, can serve as a useful reference for those seeking to establish their own benchmarks.

Technological

The set of factors in the technological dimension can be understood as an assessment of the technological pre-conditions for the implementation of DLT. In particular, the KPIs on this technological dimension focus on assessing whether, for each factor under analysis, the implementation of DLT has been successful with respect to an ideal target implementation or, otherwise, a risk for achieving the expected outcomes of the technology is derived. For each of the technological factors described in the Assessment Framework, the Evaluation Framework develops the following evaluation questions and KPIs:

- *Unified system standards*. Whilst DLT promises to harmonise technical requirements by providing unified standards, it may occur that open standards and interoperability are blocked by incompatible regulation, legal or other structural barriers. On this item, the potential evaluation question addresses: "Has the system moved towards a more unified open system?". The KPI measures this by an informed assessment of the number of standards which are being used.
- *Aggregation of data ledgers*. DLT would allow concentrating larger portions of information by aggregating more complete sets of public data. However, technical barriers to aggregation may remain. In this regard, the evaluation question addresses: "To what extent has aggregation of data occurred?". The KPI measures this by the number of data sets integrated from different domains (compared to the baseline level).
- *Automation of processes*. Whilst tasks conducted by civil servants may benefit from the automated means of storing data provided by the interconnexion between DLT and other technologies, technical barriers may remain and hinder this. For this dimension, the evaluation question addresses: "To what extent have

processes become automated?". The KPI to evaluate this is the number of management tasks that have become automated (compared to a target level).

- *Data integrity*. DLT improves data integrity through immutability, although this could not be technically achieved. The evaluation question in this regard addresses: "Has data integrity improved?". The KPI to measure this is the ratio of immutable data with respect to the target level.
- *Decentralisation*: The decentralised nature of DLT is critical for ensuring data integrity. Nevertheless, technical barriers may arise. The evaluation question for this dimension inquires: "To what extent has decentralisation occurred?". This is measured by the ratio between the number of decentralised files and the total number of files.
- *Disintermediation*: The trust built on DLT removes the need to hire, pay, and rely on a third-party entity to oversee transactions. However, barriers to disintermediation may remain, in particular since the public sector has rarely seen complete disintermediation. The evaluation question here addresses: "To what extent has disintermediation occurred?". The KPI measures the number of trusted third parties avoided (relative to a target).
- *Traceability*: The ability to identify and track the information and events associated with a product or service provided by DLT may improve public service delivery. However, traceability might not be achieved. The evaluation question in this regard inquires: "To what extent has traceability occurred?". The KPI measures this by the ratio of information that could be tracked relative to the objective ratio.

Socio-Economic

In the case of the socio-economic dimension, the aim of the Evaluation Framework is to evaluate the implementation of DLT by comparing its benefits and its costs and risks with the alternative situation previously existent. For each of the socio-economic factors described in the Assessment Framework, the Evaluation Framework deploys the following evaluation questions and KPIs:

- *Financial efficiency*. The introduction of DLT into public services could provide several advantages, which may result in a reduction of costs. However, it may occur that such a reduction of costs does not take place, if costs outweigh benefits. The evaluation question here inquires: "Have you experienced lower costs?". This is measured by an economic quantification of the financial costs and benefits of the implementation of DLT, versus the previously existent system.
- *Public value*. Public finance may support innovation that is effective and creates value for society, but benefits may not be perceived to compensate for the investment in innovation for the government or society. The evaluation question for this dimension inquires: "Has public finance supported innovation that has created value for society?". This issue is measured from a cost-benefit analysis of the implementation of DLT from a social point of view.
- *Time efficiency*. DLT can reduce the human effort required to run processes in public services, resulting in time savings. However, time efficiency for government and stakeholders may not improve if there is a lack of capacity or responses from these actors. The evaluation question in this regard is: "To what extent has time efficiency improved for the government and stakeholders?". This is measured by the number of working hours saved with the new system.

- *Environmental impact*. The introduction of DLT may provide potential environmental gains. However, it also poses a significant cost in terms of its high energy consumption, and potential environmental costs may exceed the benefits. The evaluation question here inquires: “To what extent do environmental benefits outweigh environmental costs?”. This is addressed quantifying the energy costs generated by the introduction of DLT against the potential benefits derived from the digitisation of the service.
- *Social and geographical inclusion and participation*: The usability of DLT technology remains a major roadblock to widespread adoption, and failure to reach socially/geographically excluded stakeholders is a risk of the introduction of DLT. The evaluation question for this dimension is: “To what extent have previously excluded stakeholders been included in the public service?”. The KPI on this factor measures the number of previously excluded agents which are involved in the new system after the implementation of DLT.

Organisational-Cultural

Similarly, for the Organisational-cultural dimension, the aim of the Evaluation Framework is, for each factor, to identify the benefits and the costs and risks of the implementation of DLT, in comparison with the previously existent situation. For each of the organisational-cultural factors described in the Assessment Framework, the Evaluation Framework deploys the following evaluation questions and KPIs:

- *Government culture*. DLT technology, by allowing the public to monitor the network activity, may introduce positive changes in government culture. However, in precisely those areas where the government is least transparent, the government may avoid DLT. The evaluation question for this dimension is: “To

what extent has government culture changed positively?". The KPI for measuring this issue is civil servant perception of improvement in government culture from the introduction of DLT, from a survey made to civil servants involved in the process.

- *Reduction of bureaucracy*: The use of DLT in government services aims to reduce the need for paperwork and bureaucratic intervention in administrative processes, although there is a risk that red tape is not reduced after DLT is introduced. The evaluation question in this regard is: "To what extent has red tape been reduced?". This is measured by the number of bureaucratic formalities avoided (with respect to the previously existent system) once the technology is introduced.
- *Agency coordination*: The improved coordination (inter-agency coordination and communication and coordination between civil servants and other key players) is another significant potential benefit of DLT. However, it may occur that friction between agencies is not reduced as a result of the introduction of DLT. The evaluation question here is: "To what extent has agency coordination improved?". The KPI to measure this is the time spent on coordination activities and processes (compared to the previous situation).
- *Transparency:* DLT may provide a rebalancing of power in every transaction in benefit for citizens, as a result of transparency. However, sometimes this aspect could not be relevant for citizens or could be even detrimental for public organizations. The evaluation question here is: "Is the transparency that the new system allows positive for the service?". This is measured from civil servants' perceptions on this question, based on a survey asking it to civil servants.

- *Organisational learning*: As DLT is a relatively new technology and most civil servants lack knowledge on this technology and its potential for public services, government agencies would need to train and hire technical experts in order to develop DLT applications. However, governments may fail in offering suitable training to the workforce or suffer lack of take up of training. The evaluation question for this dimension is: “To what extent has suitable training been provided?”. This is measured by the number of learning activities organized for civil servants.
- *Ownership and technology control*: DLT is still a complex technology that requires specialised knowledge for creation and management, hence there is a risk a minority of experts could concentrate power, dictating the rules of the system and how it is governed. On the contrary, the public sector could ensure “ownership” of the technology. The evaluation question here is: “To what extent can it be said the public sector has ownership of the technology?”. The KPI on this issue addresses the ratio of modules where the public sector retains decisive control, with respect to the total.
- *Civil servants’ attitudes*: As in the cases of other disruptive technologies, successful DLT adoption requires workers’ acceptance of the technology. It may happen that civil servants embrace the technology, or that they reject it. Different configurations of DLT may play a key role in this regard (Cagigas et al. 2022). The evaluation question here is: “To what extent do civil servants embrace the introduction of DLT?”. This is measured by a question, in a survey to civil servants, asking them: "Would you be willing to introduce the new system into the public service?”.

Institutional (legal and political)

The set of factors in the institutional (legal and political) dimension can be understood as a post-evaluation of the implementation of DLT in the public sector: that is, an evaluation of whether the implementation of this technology accomplishes with the legal and political conditions that are essential for achieving the results obtained from the previous dimensions. For each of the institutional (legal and political) factors described in the Assessment Framework, the Evaluation Framework deploys the following evaluation questions and KPIs:

- *Legal compliance*. DLT might be legally problematic with respect to current laws and court decisions. The evaluation question in this regard is: "Is the processing built on law compliant standards in your jurisdiction?". This is measured by an internal evaluation of the conformity with the existent relevant legislation, after it is identified by the team making the evaluation, which could result in an affirmative or in a negative answer to this question.
- *Privacy compliance*. Although encryption helps to protect DLT users' privacy, there is still a risk of re-identification and cyberattacks. This could generate a lack of trust, resulting in the lack of use of services based on this technology. The evaluation question on this regard is: "To what extent are privacy requirements adequately met?". The KPI to measure this is based on ISO 27701 (or GDPR in the case of the European Union) and evaluates the "average conformity rate" to all requirements and recommendations as assessed by an auditor or in a self-assessment exercise.
- *System security compliance*. Although security is a major benefit of DLT, it also poses a risk that should be taken into account by the system. The evaluation question here is: "Is the system ready to notify a large-scale cyber security

incident?". The KPI to measure this is based on ISO/IEC 27002 and evaluates the "average conformity rate" to all requirements and recommendations as assessed by an auditor or in a self-assessment exercise.

- *Trust by design*. The creation and maintenance of the technological systems ultimately rely on institutions either through direct management or through externalised services. For this reason, DLT requires institutional trust and institutional infrastructure. The evaluation question for this item is: "To what extent do the introduction of DLT affect citizens' trust in government?" This could be measure from civil servants' perceptions on whether the introduction of DLT increase, or decrease, citizens' trust in government with respect to the previously existent situation, from a survey to these stakeholders.
- *Citizen participation*: the use of DLT represent an opportunity for new mechanisms for citizen participation in government. However, there are several risks in this regard: DLT in public services that have actual users remain rare, DLT may not be fully public, and citizens may resist using mechanisms for participation. The evaluation question in this regard is: "To what extent are citizens participating more in government?" To measure this, the KPI is the number of end-users informed about and participating in the new system compared to the previously existent before DLT was introduced.

V. Conclusion

DLT has been heralded as the "next big thing" for nearly a decade now. Even though attention around the technology has been significant over the past years, real-world evidence of realized benefits of DLT in government are still hard to find. Existent evidence is fragmented, based on specific case studies or pilot projects, and there is a lack of a homogeneous framework which may allow to evaluate, and compare, the benefits,

costs and risks of the introduction of DLT in different cases within government activities. This paper provides a consistent multidimensional framework for evaluating the introduction of DLT in government, which encompasses four dimensions: technological, socioeconomic, organizational-cultural, and institutional (legal and political). This evaluation framework may be of use for policymakers and practitioners, as well as for researchers, aimed at evaluating and comparing the effects of DLT implementation in various government contexts. This methodical and multi-dimensional approach, as described in this paper, aims to provide a standardised framework which allow to obtain more evidence on real-case applications of DLT technology and to connect it with other real-cases, thus advancing existing knowledge of the real benefits, costs and risks of this technology in government.

Conclusions

Main results

Distributed ledger technologies (DLTs) and, in particular, blockchain, seem to offer a wide set of opportunities in our connected world. As a tamper-resistant and time-stamped database, blockchain technology enables parties with no trust in each other to exchange digital assets such as money, contracts, and records on a peer-to-peer basis without the need of a middleman. This is meant to increase efficiency and reduce costs, as well as an innovation wave of new organizational and business models. The benefits of blockchain are said to be seen in a variety of public services thanks to its increased security, transparency, and trust.

However, blockchain is still in its early stages and faces many challenges. Technical bottlenecks remain unresolved, including scalability and performance, interoperability, and the protection of personal data. There is also regulatory ambiguity and uncertainty surrounding the formal status of blockchain applications, causing additional risk for organizations interested in its deployment. As a consequence, the development of blockchain faces questions about its impact, added value, and widespread adoption. The main objective of this work has been to assess, from an economic perspective, the impact of the introduction of disruptive technologies in the provision of services by the public sector.

In the second chapter, we conduct a systematic literature review on the introduction of blockchain technology in public services. The results show that blockchain applications covered in the literature are distributed across a wide range of public services: 16 different public services are identified as potentially affected by the introduction of this technology. The public services with the highest number of

appearances in the literature are records management and healthcare. In the case of records management, blockchain is bringing time and cost efficiencies and a more secure infrastructure to this public service, although the use of this technology is still built in a context of regulatory uncertainty. In the case of healthcare, blockchain could improve the system through tracking tools, accountable transactions and more control over personal data. Other public services identified in this systematic review and analysed are international trade and customs, voting processes, environmental protection systems, public procurement and tendering, food security, digital identities, energy and social protection.

Additionally, we proposed a framework for studying the benefits, costs and risks of blockchain per societal actor involved. We note, firstly, that two actors concentrate most of the attention in the literature: governments and citizens. In contrast, civil servants receive notably less attention. For governments, we find that the most important benefits of blockchain are associated with economic efficiency and traceability (the ability to track the history, location, or origin of the product, item, or information), while the most important costs and risks are related to regulatory uncertainty and scalability (ability of the system, process, or product to handle increased demand or growth without negatively impacting performance). Regarding the impact on citizens, the literature focuses especially on the benefits of blockchain related to security and transparency, while a number of different costs and risks (in particular, those related to potential security threats) are also discussed. Finally, as far as civil servants are concerned, the literature discusses the benefits associated with the transformation of tasks performed by them and the increased possibilities for coordination, while the most important costs and risks cited are related to the lack of necessary skills, the change of organisational structure and the reduction of jobs.

According to literature, the acceptance of civil servants is a crucial risk factor in implementing technology. However, as shown in chapter 2, the role of civil servants as stakeholders has been given insufficient attention in the literature on blockchain in public services. The impact of blockchain on public sector employees and their perception of it are examined in chapter 3. Public bureaucracies may well avoid embracing disruption, despite their rhetoric on digital services and e-government. As a result, the adoption of blockchain in the public sector will be somewhat dependent on the support of the public servants themselves, particularly in situations where the technology may limit their discretion and power. According to the literature, public employees may have a variety of attitudes toward the adoption of blockchain, depending on factors like efficiency, service, the effect on public sector jobs, and discretion, among others (Janssen et al., 2020). However, one of the main limitations encountered is the scarcity of analysis regarding the study of the role of public employees in the process of implementing technologies such as blockchain.

In order to address this limitation, we conduct a vignette experiment on the introduction of blockchain for a digital identity in providing local public services, positing different configurations around a blockchain that is more or less "open" (in the sense of openness to being able to "read" and "write" on the blockchain). Through this innovative methodology for evaluating the implementation of blockchain technology in the public sector, the exercise demonstrates the usefulness of vignette experiments in assessing the innovation processes. The results of the experiment show that, in aggregate, public officials positively value the decentralisation of some bureaucratic processes, which can be delegated to citizens through the use of the decentralised technology. At the same time, public officials do not value as highly the transparency that a decentralised technology such as blockchain can offer for the management of public services and information. This

highlights the importance of considering both decentralization and transparency when implementing blockchain technology in public services to ensure a successful outcome.

Finally, in chapter 4 we addressed the question of how to conduct an evaluation for a blockchain application in the public sector. According to early pilots introducing it to the public sector, DLT's potential impact will vary depending on the context, including the type of public service. Additionally, the effects of DLT may vary for each of the involved stakeholders even within the same public service (mainly the government, civil servants and citizens). As a result, existent evidence is fragmented, and there is a lack of a homogeneous framework which may allow to evaluate, and compare, the benefits and costs of the introduction of DLT in different cases within government activities. Given the diversity of the public sector, it is essential to gain a thorough understanding of the introduction of this technology process that includes all the various factors that influence it.

The chapter presents an original and multi-dimensional evaluation framework to analyse and compare the benefits, costs and risks of specific cases of introduction of DLT in government. It is based on a set of Key Performance Indicators (KPI) in four separate dimensions: technological, socio-economic, organisational-cultural, and institutional (legal and political). This approach aims to offer a standardized framework that enables the collection of more evidence regarding real-world DLT technology applications, thereby advancing our understanding of the true advantages, disadvantages, and risks associated with this technology in the realm of government. The development of this assessment framework leads to the conclusion that there are a multitude of factors to be taken into account to ensure that the implementation of blockchain is appropriate. Each of the KPIs differ in the way they are measured, data sources, timeframe or level of

aggregation. In this sense, a multidisciplinary perspective is essential for a comprehensive analysis. The evaluation framework was designed to be used by policy-makers interested in analysing and contrasting the advantages and disadvantages of the adoption of DLT in applications of this technology in the public sector.

Practical and theoretical implications

Despite the limitations of this research, discussed at the end of each chapter, our findings may help to increase the understanding of blockchain applications in the public sector, from the innovation process to the actual impact. The literature suggests the adoption of blockchain technology by the public sector can have a variety of positive effects, such as offering citizens personalized services, boosting public trust in the government, and enhancing automation, transparency, and audibility. The use of blockchain technology in the provision of public services may have significant additional advantages, including improved data security and integrity as well as decreased operational costs and processing times. For example, a government-issued blockchain-based identity can provide time and cost savings for citizens, businesses, and the public administration when it comes to setting up, managing, and accessing identities for specific services.

However, until now, the disruptive impact of blockchain is far from what has been portrayed in various technology and business arenas over the last few years. Current blockchain-based systems do not allow for a complete de-intermediation of organizations, or the replacement of any systems currently used by public institutions for the delivery of services (Atzori, 2017). Blockchain still needs to integrate with existing systems to deliver added benefits and secure the information of citizens. A great number of existing pilots still rely on centralized systems for property details and personal information. In

contrast to a determined attempt to overcome centralisation at all costs, its deliberate maintenance calls into question the essential contribution of blockchain as a general enabling technology for public services delivery. The current complexity of public services exceeds current blockchain capabilities, particularly in handling the large number of transactions required for smart contracts. Furthermore, there are also concerns about ensuring the accuracy of electronic submissions without an impartial mediator.

In terms of policy implications related to civil servants, this work aims to contribute to the existing literature on managing change in public administration. The study makes some conclusions about how public officials should approach the adoption of a largely decentralised technology like blockchain in terms of public policy. The experiment's findings demonstrate that, overall, public servants favourably view the delegation of some bureaucratic tasks to citizens through the use of decentralised technology. Public officials, however, do not place as much value on the transparency that a decentralised technology, such as blockchain, can provide for the administration of public services and data. In conclusion, to ensure the successful implementation of a blockchain in a public service, these two factors may be crucial to be taken into account.

Finally, adoption of blockchain requires collaboration between various stakeholders, who must be able to set up, scale, and sustain the technology. Rigorous and comparable assessments of the results are crucial in determining the areas where blockchain has already made substantial improvements, where it is not necessary, and where there is room for further development. This information will allow stakeholders to make informed decisions about where to invest resources and how to allocate funding. It will also help to continue identifying the challenges and obstacles that need to be overcome to ensure the successful implementation of blockchain technology. The

evaluation framework provided in Chapter 4 seeks to facilitate this task of collecting, analysing and comparing results in order to fully understand and harness its potential.

Future research agenda

Throughout this work, we have shown how the adoption of blockchain technology by government has the potential to transform public services and improve citizens' lives in significant ways. However, we have also highlighted that the implementation of blockchain in government raises multiple and complex social, economic, and political questions that require further investigation. The need to update knowledge on the subject is even greater in the case of a few years' old technology such as blockchain, where sudden innovations or pioneering applications can change the perception of the technology in a short period of time. Furthermore, given the complexity involved in technological innovation processes in government, knowledge must be developed both from technical and technological disciplines and from other disciplines closer to the social sciences.

First, we have carried out a study of the blockchain applications in the public sector literature from the point of view of the different dimensions (technological, socio-economic, organizational-cultural, institutional-legal) and also from the point of view of the different stakeholders involved in the innovative process. However, evidence on real-world cases is still scarce and only slightly illuminating with respect to the concrete possibilities of blockchain technology. It is necessary to continue this ambitious path by combining it with reports that include a more detailed description of the different use cases around the world (Lindman et al., 2020; Bosch et al., 2022). However, as detailed in chapter two, two aspects should be considered in evaluating blockchain use cases in public services. Firstly, the internal validity of the case, which involves evaluating the

effectiveness of the blockchain solution and comparing it to alternative options. Secondly, the external validity of the analysis, which assesses whether the specific context of the case makes it comparable to other technological, socio-economic, legal, and cultural environments. By conducting rigorous evaluations of blockchain use cases based on these two aspects, researchers can gain a deeper understanding of the potential of blockchain in improving public service provision. This will inform decision-making and ensure that blockchain is implemented in a way that benefits society as a whole.

Second, it is important to acknowledge that much of the existing literature and a significant portion of this research (excluding Chapter 3) is exploratory in nature. To fully understand the potential benefits, costs, and risks associated with blockchain in the public sector, more comprehensive evaluation will be needed once there is a larger number of successful and well-documented pilot projects. Further research will also benefit from using statistical methods (of causal inference, in cases where possible) to generalize findings and gain a better understanding of public sector blockchain initiatives. This recommendation can be extended to the analysis of other innovation experiences in the public sector where knowledge of cases from an empirical point of view is still limited (De Vries et al., 2016).

Third, we have shown how blockchain technology can impact trust in government. It has potential to create a new form of trust through its features of immutability, transparency, and auditability. However, the effect on trust is not clear cut since greater transparency can lead to both positive and negative outcomes for trust depending on the specific application as well and the opinion might differ depending on the stakeholder. Our results show that a shift of responsibility from public officials to citizens through blockchain is viewed as a positive aspect of service provision. At the same time, increased

transparency can improve legitimacy and trust, but may also infringe on personal rights and induce criticism of public administration that could lead to a major rejection of the technology by public servants. Current blockchain implementations do not raise concerns due to a limited impact, but future disruptive ones may create tension between disintermediating government and earning trust through democratic processes.

Finally, as the development of evidence regarding blockchain applications progresses, it is increasingly possible to differentiate between projects with limited or even counterproductive impact and more stimulating projects, such as EBSI. As previously described, EBSI is the first pan-European, public-driven blockchain initiative aimed at improving public services for all of Europe. The infrastructure of EBSI is decentralized across the EU, with many synchronized copies hosted in its network of European nodes distributed among EU member states. This aspect makes EBSI a virtually unique case study in terms of developing international governance in and through the blockchain. The first cross-border pilot program related to verifiable credentials in education started in July 2021. To create the so-called "multi-university pilot", which identified, designed 6 cross-border scenarios, brought together 2 European university alliances and 11 universities from 11 different countries. In the near future it will be essential to analyse the development of verifiable credentials in both education and social security to assess the true potential of blockchain for large-scale projects.

Conclusiones

Principales resultados

La cadena de bloques o blockchain y las tecnologías de libro mayor distribuido (DLT) ofrecen un amplio abanico de oportunidades en nuestro mundo interconectado. Como base de datos a prueba de manipulaciones y con sello temporal, la tecnología blockchain permite a las partes que no confían entre sí intercambiar activos digitales como dinero, contratos y registros de igual a igual sin necesidad de intermediarios. Con ello se pretende aumentar la eficiencia y reducir los costes, así como desencadenar una ola de innovación de nuevos modelos organizativos y empresariales. Se han identificado beneficios potenciales de blockchain en diversos sectores gracias a su mayor seguridad, transparencia y confianza.

Sin embargo, blockchain está aún en sus primeras fases y se enfrenta a muchos retos. Siguen sin resolverse cuellos de botella técnicos, como la escalabilidad y el rendimiento, la interoperabilidad y la protección de los datos personales. También existe ambigüedad normativa e incertidumbre en torno al estatus formal de las aplicaciones de blockchain, lo que supone un riesgo adicional para las organizaciones interesadas en su implantación. En consecuencia, el desarrollo de blockchain se enfrenta a interrogantes sobre su impacto, valor añadido y adopción generalizada. El objetivo principal de este trabajo ha sido evaluar, desde una perspectiva económica, el impacto de la introducción de tecnologías disruptivas en la prestación de servicios por parte del sector público.

En el segundo capítulo, mostramos cómo las aplicaciones de blockchain estudiadas por la literatura están distribuidas en una amplia gama de servicios públicos. Identificamos 16 servicios públicos potencialmente afectados por la introducción de esta tecnología. Los servicios públicos con mayor número de referencias en la literatura son

la gestión de registros y la sanidad. En el caso de la gestión de registros, blockchain aporta a este servicio público una mejora de eficiencia en términos de tiempo y costes y una infraestructura más segura, aunque el uso de esta tecnología también muestra una serie de incertidumbres regulatorias. En el caso de la sanidad, blockchain podría mejorar el sistema a través de herramientas de seguimiento, transacciones dotadas de una mayor rendición de cuentas y más control sobre los datos personales. Otros servicios públicos identificados en esta revisión sistemática y analizados en más de dos registros son el comercio internacional y las aduanas, los procesos de votación, los sistemas de protección medioambiental, las compras y licitaciones públicas, la seguridad alimentaria, las identidades digitales, la energía y las actividades de protección social.

Además, proponemos un marco para estudiar los beneficios, costes y riesgos de blockchain por actor social implicado. Observamos, en primer lugar, que dos actores concentran la mayor parte de la atención en la literatura: los gobiernos y los ciudadanos. En cambio, los empleados públicos reciben notablemente menos atención. En el caso de los gobiernos, encontramos que los beneficios más importantes de blockchain están asociados a la eficiencia y la trazabilidad, mientras que los costes y riesgos más importantes están relacionados con la incertidumbre regulatoria y la escalabilidad. En cuanto al impacto sobre los ciudadanos, la literatura se centra especialmente en los beneficios de blockchain relacionados con la seguridad y la transparencia, mientras que también se discuten otros costes y riesgos, en particular, los relacionados con posibles amenazas a la seguridad. Por último, en lo que respecta a los empleados públicos, la literatura discute los beneficios asociados a la transformación de las tareas realizadas y las mayores posibilidades de coordinación, mientras que los costes y riesgos más importantes citados están relacionados con la falta de las competencias necesarias, el cambio de la estructura organizativa y la reducción de puestos de trabajo.

Para que blockchain pueda utilizarse en el sector público, sus empleados deben formar parte del proceso innovativo. El impacto de blockchain en los empleados del sector público y su percepción del mismo se examinan en el capítulo 3. Es posible que las burocracias públicas eviten abrazar la disrupción, a pesar de su retórica sobre los servicios digitales y la administración electrónica. En consecuencia, la adopción de blockchain en el sector público dependerá en cierta medida del apoyo de los propios empleados públicos, sobre todo en situaciones en las que la tecnología puede limitar su discreción y poder. Según la literatura, los empleados públicos pueden tener diversas actitudes hacia la adopción de blockchain, dependiendo de factores como la eficiencia, el servicio, el efecto sobre los puestos de trabajo del sector público y la discreción, entre otros (Janssen et al., 2020). Sin embargo, una de las principales limitaciones encontradas es la escasez de análisis relativos al estudio del papel de los empleados públicos en el proceso de implantación de tecnologías como blockchain.

Para abordar esta limitación, la presente tesis lleva a cabo un experimento en viñetas (*vignette experiment*) sobre la introducción de blockchain para una identidad digital en la prestación de servicios públicos locales, planteando diferentes configuraciones en torno a una blockchain más o menos "abierta" (en el sentido de abierta a poder "leer" y "escribir" en la blockchain de acuerdo con la iniciativa del ciudadano individual). A través de esta metodología innovadora para evaluar la implantación de la tecnología blockchain en el sector público, el ejercicio demuestra la utilidad de los experimentos con viñetas para evaluar los procesos de innovación. Los resultados del experimento indican que, en general, los funcionarios públicos que participaron en el experimento tienen una visión positiva hacia la descentralización de los procesos burocráticos, pero se muestran menos entusiastas con respecto a la transparencia que la tecnología blockchain puede ofrecer para la gestión de los servicios públicos y la

información. Esto subraya la importancia de tener en cuenta tanto la descentralización como la transparencia a la hora de implantar la tecnología blockchain en los servicios públicos para garantizar un resultado satisfactorio.

Por último, el capítulo 4 aborda la cuestión de cómo llevar a cabo una evaluación para una aplicación de blockchain en el sector público. Según los primeros proyectos piloto de introducción en el sector público, el impacto potencial de las tecnologías de registro distribuido (*DLT*) podrá variar en función del contexto, incluido el tipo de servicio público. Además, los efectos de DLT pueden variar para cada una de las partes interesadas, incluso dentro del mismo servicio público (principalmente la administración, los empleados públicos y los ciudadanos). En consecuencia, las pruebas existentes están excesivamente fragmentadas, y se carece de un marco homogéneo que permita evaluar y comparar los beneficios y los costes de la introducción de la DLT en distintos casos dentro de las actividades gubernamentales. Dada la diversidad del sector público, es esencial comprender a fondo el proceso de introducción de esta tecnología, incluyendo todos los diversos factores que influyen en él.

El capítulo presenta un marco de evaluación multidimensional para analizar y comparar los beneficios, costes y riesgos de casos concretos de introducción de la DLT en la Administración. Se basa en un conjunto de indicadores clave de rendimiento (*Key Performance Indicators, KPI*) en cuatro dimensiones distintas: tecnológica, socioeconómica, organizativa-cultural e institucional (jurídica y política). Este enfoque tiene por objetivo ofrecer un marco normalizado que permita reunir más pruebas sobre las aplicaciones de la tecnología DLT en el mundo real, avanzando así en la comprensión de las verdaderas ventajas, desventajas y riesgos asociados a esta tecnología en el ámbito de la administración pública. Se ha diseñado para que sea utilizado por responsables de

políticas públicas interesados en analizar y contrastar las ventajas y desventajas de la adopción de DLT en aplicaciones de esta tecnología en el sector público.

Implicaciones prácticas y teóricas

A pesar de las limitaciones de esta investigación, comentadas al final de cada capítulo, sus resultados pueden ayudar a comprender mejor las aplicaciones de blockchain en el sector público, desde el proceso de innovación hasta el impacto real. Los resultados obtenidos indican que la adopción de la tecnología blockchain por parte del sector público puede tener una serie de efectos positivos, como ofrecer a los ciudadanos servicios personalizados, aumentar la confianza del público en el gobierno y mejorar la automatización, la transparencia y la audibilidad. El uso de la tecnología blockchain en la prestación de servicios públicos puede tener importantes ventajas adicionales, como la mejora de la seguridad y la integridad de los datos, así como la reducción de los costes operativos y los tiempos de procesamiento. Por ejemplo, una identidad basada en blockchain emitida por el gobierno puede suponer un ahorro de tiempo y costes para los ciudadanos, las empresas y la administración pública a la hora de crear, gestionar y acceder a identidades para servicios específicos.

Sin embargo, hasta ahora, el impacto disruptivo de blockchain dista mucho de lo que se ha retratado en diversos ámbitos tecnológicos y empresariales en los últimos años. Los sistemas actuales basados en blockchain no permiten una completa desintermediación de las organizaciones, ni la sustitución de ningún sistema utilizado actualmente por las instituciones públicas para la prestación de servicios, como en ocasiones se planteaba (Atzori, 2017). Blockchain aún necesita integrarse con los sistemas existentes para ofrecer ventajas añadidas y proteger la información de los ciudadanos. Un gran número de proyectos piloto existentes siguen dependiendo de

sistemas centralizados para los registros de propiedad e información personal. En contraste con un intento decidido de superar la centralización a toda costa, su mantenimiento deliberado cuestiona la contribución esencial de blockchain como tecnología de aplicación general habilitadora para la prestación de servicios públicos. La complejidad actual de los servicios públicos supera las capacidades actuales de blockchain, en particular a la hora de gestionar el gran número de transacciones que requieren los contratos inteligentes. Además, también preocupa la necesidad de garantizar la exactitud y verosimilitud de la información introducida en el registro sin la presencia de un mediador imparcial.

En términos de implicaciones de políticas públicas relacionadas con los empleados públicos, este trabajo pretende contribuir a la literatura existente sobre la gestión del cambio en la administración pública. El estudio extrae algunas conclusiones sobre cómo deberían enfocar los empleados públicos la adopción de una tecnología descentralizada como blockchain en términos de política pública. Los resultados del experimento demuestran que, en general, los empleados públicos ven con buenos ojos la delegación de algunas tareas burocráticas a los ciudadanos mediante el uso de tecnología descentralizada. Los empleados, sin embargo, no valoran de forma tan positiva la transparencia que una tecnología descentralizada, como blockchain, puede aportar a la administración de servicios y datos públicos. En conclusión, para garantizar el éxito de la implantación de una blockchain en un servicio público, puede ser crucial tener en cuenta cada uno de estos dos factores.

Por último, la adopción de blockchain requiere la colaboración entre diversas partes interesadas, que deben ser capaces de poner en marcha, ampliar y mantener la infraestructura tecnológica. Una evaluación rigurosa y comparable de los resultados es

crucial para determinar los ámbitos en los que blockchain ya ha aportado mejoras sustanciales, aquellos en los que no es necesario y aquellos en los que hay margen para un mayor desarrollo. Esta información permitirá a las partes interesadas tomar decisiones informadas sobre dónde invertir los recursos y cómo asignar la financiación. También ayudará a seguir identificando los retos y obstáculos que deben superarse para garantizar el éxito de la implantación de la tecnología blockchain. El marco de evaluación que se ofrece en el capítulo 4 pretende facilitar esta tarea de recopilación, análisis y comparación de resultados para comprender y aprovechar plenamente su potencial.

Futura agenda de investigación

Esta tesis doctoral ha mostrado cómo la adopción de la tecnología blockchain por parte del sector público tiene el potencial de transformar los servicios públicos y mejorar la vida de los ciudadanos de forma significativa. Sin embargo, también hemos destacado que la implantación de blockchain en la administración plantea múltiples y complejas cuestiones sociales, económicas y políticas que requieren una mayor investigación. La necesidad de actualizar los conocimientos sobre el tema es aún mayor en el caso de una tecnología con pocos años de antigüedad como blockchain, en la que innovaciones repentinas o aplicaciones pioneras pueden cambiar la percepción de la tecnología en un corto periodo de tiempo. Además, dada la complejidad que entrañan los procesos de innovación tecnológica en la administración, es necesario desarrollar conocimiento tanto desde disciplinas técnicas y tecnológicas como desde otras más cercanas a las ciencias sociales.

En primer lugar, la presente tesis doctoral ha realizado un estudio de las aplicaciones de blockchain en la literatura del sector público desde el punto de vista de las diferentes dimensiones (tecnológica, socioeconómica, organizativo-cultural,

institucional-legal) y también desde el punto de vista de los diferentes actores involucrados en el proceso innovador. Sin embargo, los datos sobre casos reales siguen siendo escasos y poco esclarecedores respecto a las posibilidades concretas de la tecnología. Es necesario continuar el ambicioso camino presentado combinándolo con informes que incluyan una descripción más detallada de los diferentes casos de uso en todo el mundo (Lindman et al., 2020; Bosch et al., 2022). Sin embargo, como se detalla en el capítulo dos, deben tenerse en cuenta dos aspectos a la hora de evaluar los casos de uso de blockchain en los servicios públicos. En primer lugar, la validez interna del caso, que implica evaluar la eficacia de la solución blockchain y compararla con opciones alternativas. En segundo lugar, la validez externa del análisis, que evalúa si el contexto específico del caso lo hace comparable a otros entornos tecnológicos, socioeconómicos, jurídicos y culturales. Mediante la realización de evaluaciones rigurosas de los casos de uso de blockchain basadas en estos dos aspectos, los investigadores pueden obtener una comprensión más profunda del potencial de blockchain para mejorar la prestación de servicios públicos. De este modo, se fundamentará la toma de decisiones y se garantizará que blockchain se implante de un modo que beneficie a la sociedad en su conjunto.

En segundo lugar, es importante reconocer que gran parte de la bibliografía existente y una parte significativa de esta investigación (excluyendo el capítulo 3) son de carácter exploratorio. Para comprender plenamente los posibles beneficios, costes y riesgos asociados a blockchain en el sector público, será necesaria una evaluación más exhaustiva una vez que haya un mayor número de proyectos piloto con éxito y bien documentados. Las investigaciones futuras también se beneficiarán del uso de métodos estadísticos (de inferencia causal, cuando sea posible) para generalizar los resultados y obtener una mejor comprensión de las iniciativas. Esta recomendación puede hacerse extensiva al análisis de otras experiencias de innovación en el sector público, donde el

conocimiento de casos desde un punto de vista empírico sigue siendo limitado (De Vries et al., 2016).

En tercer lugar, hemos mostrado cómo la tecnología blockchain puede tener un impacto en la confianza ciudadana en la administración. Tiene potencial para crear una nueva forma de confianza a través de sus características de inmutabilidad, transparencia y auditabilidad, pero el efecto sobre la confianza no está claro, ya que una mayor transparencia puede conducir a resultados tanto positivos como negativos para la confianza, dependiendo también de la aplicación específica y la opinión podría diferir dependiendo de la parte interesada. Nuestros resultados muestran que el desplazamiento de la responsabilidad de los funcionarios públicos a los ciudadanos a través de blockchain se considera un aspecto positivo de la prestación de servicios. Al mismo tiempo, una mayor transparencia puede mejorar la legitimidad y la confianza, pero también puede vulnerar los derechos personales y dar lugar a críticas contra la administración pública, que puede llevar a un intenso rechazo por parte de los empleados públicos. Las implantaciones actuales de blockchain no suscitan preocupación en ese sentido, pues su impacto es limitado, pero las futuras de carácter disruptivo pueden crear tensiones entre la desintermediación del gobierno y la obtención de confianza a través de procesos democráticos.

Por último, a medida que avanza el desarrollo de pruebas relativas a las aplicaciones de blockchain, es cada vez más posible diferenciar entre proyectos con un impacto limitado o incluso contraproducente y proyectos más estimulantes, como EBSI. Como se ha descrito anteriormente, EBSI es la primera iniciativa paneuropea de blockchain impulsada por el sector público, cuyo objetivo es mejorar los servicios públicos para toda Europa. La infraestructura de EBSI está descentralizada en toda la UE,

con numerosas copias sincronizadas alojadas en su red de nodos europeos distribuidos entre los estados miembros de la UE. Este aspecto, que convierte a EBSI en un caso de estudio prácticamente único en cuanto al desarrollo de la gobernanza internacional en y a través de la blockchain. El primer programa piloto transfronterizo relacionado con credenciales verificables en educación comenzó en julio de 2021, para crear el llamado "piloto multiuniversitario", que identificó y diseñó 6 escenarios transfronterizos, reuniendo a 2 alianzas universitarias europeas y 11 universidades de 11 países diferentes. En un futuro próximo será esencial analizar el desarrollo de las credenciales verificables tanto en educación como en seguridad social, así como la traducción material del resto de casos de uso que se están desarrollando, lo que permitirá certificar el verdadero potencial de blockchain para proyectos a gran escala.

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Appendix A: Chapter 2 supplemental material

SUPPLEMENTAL MATERIAL S1: PRISMA CHECKLIST

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	23
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	(Provided in the published paper)
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what isalready known.	23-28
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design.	27-28
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., web address), and, if available, provide registration information including registration number.	30
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	30-31
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	32-33
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	32-33
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	33-34
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	35-36
Data items	11	List and define all variables for which data were sought (e.g., PICOS,funding sources) and any assumptions and simplifications made.	NA
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	NA
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	NA

Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	NA

SUPPLEMENTAL MATERIAL S2: CLASSIFICATION OF RECORDS INCLUDED IN THE SLR

Authors	Year	Method	Policy Sector	Objective
B. Abelseth	2018	Case Study	Recreational	Proposes a permissioned blockchain tracking system to regulate consumption of cannabis in Canada
R. Adeonato, S. Pournouri	2020	Empirical Case Study	Digital Identity	Studies the case of E-Government in Estonia and the role of Blockchain
R. Agustin, D. Susilowati	2019	Case Study	Public Procurement	Examines the potential use of blockchain for public procurement in Indonesia from a theoretical perspective
D. Allen et al.	2019	Theoretical Research Application	Trade & Customs	Analyses the application of blockchain to reduce the trade costs and increase trusted information along supply chains
D. Allen et al.	2020	Abstract Analysis	Not applicable	Theoretically develops a model of institutional innovation and proposes its implications for innovation policy
D. Allessie et al.	2019	Case Study	Trade & Customs	Investigates the impact of blockchain on the governance of the movement of excise goods under duty exemptions
K. Anitha Kumari et al.	2020	Case Study	Healthcare	Studies the context of blockchain application in the Indian healthcare system
C. Aristidou, E. Marcou	2019	Abstract Analysis	Not applicable	Review of the potential benefits and implication of blockchain for governments
M. Atzori	2017	Abstract Analysis	Not applicable	Analyses blockchain application from a political perspective including consequences of decentralized governance of blockchain
D. Bentley	2019	Theoretical Research Application	Tax system	Studies the implications of technological transformation and how those changes affect tax administration
C. Berg et al.	2018	Abstract Analysis	Not applicable	Identifies the structural economic effect of institutional innovation caused by blockchain with a focus on disintermediation, dehierarchicalisation and private provision of infrastructure
J. Bernal Bernabe et al.	2019	Systematic Review	Not applicable	Reviews the current state of art on privacy-preserving mechanisms, main challenges as well as its applicability towards eGovernment, eHealth and smart cities.
S. Bhatia, A. Wright de Hernandez	2019	Theoretical Research Application	Records Management	Examines the potential of blockchain for archivists and records managers
S. Bhattacharya et al.	2019	Theoretical Research Application	Healthcare	Analyses the benefits and challenges of blockchain for healthcare systems
M. Borole et al.	2019	Theoretical Research Application	Social Protection	Examines blockchain technology to create a decentralized, direct and transparent system for benefit transfers
C. Brown-Liburd et al.	2019	Theoretical Research Application	Public Accounting	Proposes replacing current government intervention programs with a new approach based on Bid Data and blockchain technology
R. Carvalho	2019	Theoretical Research Application	Public Procurement	Addresses challenges of blockchain and smart contracts such as data protection and immutable data when implemented for public procurement
Y. Chang et al.	2019	Theoretical Research Application	Trade & Customs	Provides a synthesis of the challenges in global supply chain and international trade operations

S. Davidson et al.	2018	Abstract Analysis	Not applicable	Argues that blockchain constitutes an institutional technology for economic coordination and governance
P. De Flippi, S. Hassan	2016	Abstract Analysis	Not applicable	Analyses the implications of blockchain and smart contracts for law and their potential drawbacks
D. Dhagarra et al.	2019	Case Study	Healthcare	Examines the use of Big data and blockchain in the Indian healthcare system along with its current challenges