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Digitalization in the European Public Sector: A Labor-saving technology?

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"*Everything that can be automated will be automated.*"
Shoshana Zuboff
Scholar and author

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Abstract

This dissertation presents a multi-method exploration of the relationship between digitalization and the public sector workforce in European countries. The contents are a collection of papers structured into five chapters. Chapter One introduces the research project and discusses the motivation, conceptual issues, and research strategy. Chapters 2, 3, and 4 employ different methodologies to provide a broad and variegated view of the impacts of digitalization on the public sector workforce. Chapter 5 concludes this work.

Chapter 2, titled "Unveiling Patterns in Digital Government Research: A Structural Topic Modeling Approach for Literature Review," uses an innovative approach to a literature review by applying Structural Topic Modeling (STM), an unsupervised machine-learning technique. This technique analyzes a corpus of over 6,600 abstract texts from the Digital Government Reference Library. STM allows for the systematic analysis of large quantities of text data, enabling the identification and quantification of various topics in a selected corpus. It also provides for mapping the scientific discipline under review and exploring thematic evolution over time. The application of STM in this chapter has led to the identification of thirty topics, four of which are related to emerging automation technologies such as artificial intelligence, cloud infrastructure, blockchain, and the Internet of Things. These topics are prevalent over time, indicating a growing scholarly interest in these areas. Importantly, this chapter highlights the emergence of a promising new subfield in the literature that explores the relationship between automation technologies and the public sector workforce. Chapter 3, "Digitalization and the Public Sector Workforce: A Panel Data Exploration of 20 European Countries," explores the relationship between digitalization and selected public employment indicators in 20 European countries from 2008 to 2018. According to the analysis conducted in this Chapter, digitalization appears to be something other than a labor-saving technology in the European public sector in aggregate terms. However, when the data is analyzed at an occupational level, it suggests a polarization effect between high-skill and low-skill occupations. Furthermore, digitalization negatively and significantly impacts the public sector wage bill, implying that digitalization allows for the automation of some tasks, reducing the need for human labor with a labor cost-reducing effect. This chapter provides a nuanced view of the impacts of digitalization on the public sector workforce, highlighting the complexity of this relationship. Chapter 4, "Digitalization and the Public Sector Workforce: Unbundling the Estonian Case," provides an in-depth case study of Estonia. This country has emerged as a regional leader in e-government metrics. The chapter employs a qualitative approach, interviewing nine subject matter experts with experience in the Estonian e-government system and analyzing secondary sources to explore the effects of advanced digitalization on the Estonian public sector workforce. The analysis reveals that digitalization has significantly transformed the functions and task content of street-level bureaucrats and other public sector workers. It has led to redesigning public sector front-office, back-office, and support services into a digitally enabled shared service model. This transformation implies a shift in the mode of service delivery and signals a

fundamental change in the working dynamics of the public sector workforce. Chapter 5, “Concluding discussion,” summarizes and discusses the findings of the project, and each of the individual chapters provides observations of managerial and policy implications, highlights the limitations of the current study, and formulates potential avenues for further research.

Keywords: public sector innovation, digital government, public-sector workforce, Europe public sector, multi-method approach

Abstract (Italiano)

La presente Tesi, utilizzando un approccio "*multi-method*", esplora la relazione tra digitalizzazione e forza lavoro del settore pubblico nei paesi europei. L'elaborato consiste in una raccolta di articoli suddivisi in cinque capitoli. Il primo capitolo introduce il progetto di ricerca, ne discute la motivazione, il quadro concettuale e la strategia di ricerca. I capitoli 2, 3 e 4, impiegando diverse metodologie, analizzano in termini aggregati e attraverso un caso di studio approfondito, diversi aspetti della digitalizzazione del settore pubblico europeo e del suo impatto sulla forza lavoro.

Il capitolo 2, intitolato "*Unveiling Patterns in Digital Government Research: A Structural Topic Modeling Approach for Literature Review*", utilizza un approccio innovativo alla revisione della letteratura applicando lo Structural Topic Modeling (STM), una tecnica di *Unsupervised learning*. Tale tecnica viene utilizzata per analizzare oltre 6.600 abstract recuperati dalla Digital Government Reference Library. Lo STM consente l'analisi sistematica di grandi quantità di dati di testo, permettendo l'identificazione e la quantificazione di vari argomenti in un insieme di pubblicazioni. Consente inoltre la mappatura della disciplina scientifica in esame e l'esplorazione della sua evoluzione tematica nel tempo. L'applicazione di STM in questo capitolo ha portato all'identificazione di trenta argomenti, quattro dei quali, relativi a tecnologie di automazione emergenti come intelligenza artificiale, infrastruttura cloud, blockchain e Internet of Things. Questi argomenti mostrano un'incidenza crescente nel tempo, indicando un aumento di interesse accademico in queste aree. È importante sottolineare che questo capitolo identifica un nuovo sottocampo promettente nella letteratura che esplora la relazione tra le tecnologie di automazione e la forza lavoro del settore pubblico. Il capitolo 3, "*Digitalization and the Public Sector Workforce: A panel data exploration of 20 European countries*", ha come obiettivo colmare una lacuna significativa nella letteratura esistente riguardante l'impatto delle tecnologie digitali sulla forza lavoro del settore pubblico. Questo capitolo esplora la relazione tra digitalizzazione e indicatori selezionati di impiego pubblico in 20 paesi europei nel periodo 2008 - 2018. L'analisi rivela che la digitalizzazione non sembra essere una tecnologia labor-saving all'interno del settore pubblico europeo in termini aggregati. Tuttavia, quando i dati vengono analizzati a livello di categorie occupazionali, suggeriscono un effetto di polarizzazione tra mansioni altamente qualificate e mansioni poco qualificate. Inoltre, la digitalizzazione ha un effetto negativo e significativo sulle retribuzioni del settore pubblico, suggerendo che la digitalizzazione consente l'automazione di alcune attività, riducendo la necessità di manodopera umana e quindi l'incidenza dei salari sui costi complessivi. Questo capitolo fornisce una visione articolata degli impatti della digitalizzazione sulla forza lavoro del settore pubblico, evidenziando la complessità di questa relazione. Il capitolo 4, "*Digitalization and the Public Sector Workforce: Unbundling the Estonian Case*", fornisce uno studio approfondito sul caso dell'Estonia, un paese che è emerso come leader regionale nelle metriche di e-government. Il capitolo utilizza un approccio qualitativo e si pone come obiettivo esplorare gli effetti della digitalizzazione avanzata sulla forza lavoro del settore pubblico estone. Nove interviste sono state condotte con esperti in materia di sistemi di e-government in Estonia. Inoltre una serie di fonti secondarie sono state analizzate per

esplorare gli effetti della digitalizzazione avanzata sulla forza lavoro del settore pubblico estone. L'analisi rivela che la digitalizzazione ha trasformato in modo significativo le funzioni e il contenuto dei compiti dei *street-level bureaucrats* e di altri lavoratori del settore pubblico. Ha portato alla riprogettazione dei servizi di *front-office*, *back-office* e supporto del settore pubblico in un modello di servizio condiviso abilitato digitalmente. Questa trasformazione ha significato un cambiamento nella modalità di erogazione dei servizi e segnala un cambiamento fondamentale nelle dinamiche lavorative della forza lavoro del settore pubblico. Il capitolo 5, "Discussione conclusiva", riassume e discute i risultati del progetto e di ciascuno dei singoli capitoli e fornisce osservazioni, implicazioni gestionali e politiche, evidenzia i limiti dello studio attuale e formula suggerimenti per future ricerche.

Keywords: innovazione del settore pubblico, governo digitale, forza lavoro del settore pubblico, settore pubblico europeo, approccio multimetodo

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CHAPTER I - INTRODUCTION

1. Research background and motivation

The advent of digital technologies has significantly transformed various sectors, with the public sector being no exception. The integration of digital technologies into public administration, also known as Digital Government (DG), is the subject matter of a vibrant multidisciplinary field that intersects with numerous academic disciplines such as information systems, public administration, political science, economics, and innovation studies.

The public sector is, in some jurisdictions, the largest employer in a wide array of occupations and industries (i.e., defense, public administration, health services, and education, among others). Also, it is considered one of the largest adopters of information and communication technologies (ICT). In addition, the public sector commands a large, diverse, and generally highly educated workforce. The size and economic footprint of the public sector are undeniable; government expenditure as a percentage of GDP in European members of the OECD exceeded 50% in 2020. In terms of workforce, in 2019, employment in general government as a share of total employment averaged 18% for OECD countries (OECD, 2021).

The pursuit of digital technologies to foster innovation has been on the political and social agenda of the European Union, at least explicitly, for the last decade. Cumulative investments in crucial infrastructure, iterative efforts to implement regional strategies, and the practical enactment of digital government programs by some European countries have resulted in the region's leadership in indicators such as the United Nations' E-Government Development Index for measuring digital government performance.

Recent technological developments have allowed the deployment of digital technologies, digital platforms, and digital infrastructures by private corporations and public organizations with profound implications for work organization (Nambisan et al., 2019). The global health emergency of the pandemic accelerated these trends. Still, it has made even more visible issues like the digital divide or the panoptical surveillance enabled by digital technologies (Faraj et al., 2021).

Despite the importance of the public sector as an employer and as a user and developer of technology, most of the extant empirical research exploring the impact of technology on labor has been conceptualized and framed with assumptions for organizations operating in market conditions (Calvino & Virgillito, 2018). The relative scarcity of systematic studies on the technology-work nexus in the public sector partly has to do with the more general difficulties of measuring labor productivity and innovation itself when dealing with non-market conditions (Arundel et al., 2019; De Vries et al., 2016; Gallouj & Zanfei, 2013; Windrum, 2008). For decades, the usual procedure for measuring productivity in the public sector has been estimating outputs using inputs (Dunleavy, 2017). This accounting practice should be updated by using novel methodologies and better use of indicators.

This lack of research is particularly noteworthy given the growing influence of digital technologies on various aspects of modern society, including how governments deliver services and interact with citizens. The impact of digital technologies on public sector workers has been conceptually acknowledged by the literature (MacLean & Titah, 2021; Plesner et al., 2018). Nowadays, most public services are users of ICT in daily operations. However, the impact of digital technologies on the organization of work and its workforce still needs to be assessed and estimated. Measuring and estimating these impacts is perhaps the most critical empirical challenge in the literature (Liva et al., 2020; Seri & Zanfei, 2013). Calls for more empirical research are deemed a common area of agreement (Hartley et al., 2016).

The European public sector is heterogeneous in scale and scope; it responds to intricate institutional factors, path dependencies, socio-political arrangements, and economic and fiscal constraints. The industries in which public organizations operate are very diversified and have distinct degrees of technological sophistication and diverse degrees of interaction with citizens and firms (Cepparulo & Zanfei, 2021). Public organizations operate at different levels, national, regional, or local; some compete in quasi-markets or act as monopolies.

As for their functional profile, some organizations provide public services in labor-intensive sectors such as healthcare or education, while others provide regulatory oversight,

manage registries and taxation agencies, administer social security schemes, or conduct traditional public sector functions such as defense or police. As a result of this heterogeneity, over the past 20 years, governments at the national, regional, and local levels all over the world have deployed and implemented digital technologies in their operations, aiming at improving the quality of the services provided and the rationalization of their operations in a variety of ways and with diverse results.

The interplay between digitalization and work is intricate and multifaceted. Its impacts manifest differently across organizations, industries, and employee groups, underscoring the complexity of the digitalization process (Doellgast & Wagner, 2022). The global health emergency in early 2020 acted as a catalyst, promoting a newfound awareness and increasing research interest in the subject matter (Dingel & Neiman, 2020; Faraj et al., 2021; Leonardi, 2021; Mazzucato & Kattel, 2020; Nagel, 2020).

The digitalization of government, the novel design of public services, the digitally enabled co-production of public services, and the deployment of artificial intelligence initiatives may change the labor input from public officials by including unaccounted and uncompensated labor inputs by users and algorithms, also adjusting the skills demanded by public officials, hence making relevant to extend the debate on the effects of technological change on labor in a public sector context.

The organization studies literature has identified diverse effects of digitalization on labor; these include the automation of work, the creation or elimination of jobs, and deskilling or reskilling of work, but also negligible or no organizational changes whatsoever (Barley & Kunda, 2001). The digitalization process is allowing a more specific division of labor into the minor possible tasks, opening more opportunities for the implementation of self-service solutions, and facilitating scenarios for the co-production of public services (Scupola & Mergel, 2021), turning each citizen and user into “his or her administrator, caseworker and bureaucrat” (Schou & Hjelholt, 2018), and possibly generating administrative burden of citizens (Madsen et al., 2021). Therefore, it is deemed pertinent and timely to extend the scholarly exploration of the effects of technological change in the organization of work in public organizations and the potential consequences for the public sector workforce.

The growing body of literature on public sector innovation and digital government has significantly contributed to our understanding of public administration's unique knowledge generation and utilization processes. However, as academic exploration continues to grow in this realm, there remains a critical gap in our understanding of the extent to which automation technologies have been comprehensively studied, particularly concerning their implications for and interactions with workforce organizations in the public sector. This leads us to formulate (RQ1): *How are automation technologies studied concerning the public sector workforce in the Digital Government field?*

The relationship between automation technologies and the workforce in the public sector is deemed a gap in the literature worthy of exploring; however, an evident limitation is the scarce availability of granular, high-quality, and cross-country comparable datasets. Nonetheless, there is a pressing need for the exploitation of available statistical data despite its inherent limitations, leading us to formulate (RQ2): Does digitalization in the European public sector affect the demand and labor composition of the public sector workforce?

The intricate relationships between digitalization and work, involving the interplay of technology, politics, and institutional factors, necessitate a multifaceted research approach. Technological change will not impact two jurisdictions in the same way; several factors must be considered to understand its effects: demographics, human capital, technological readiness, regulation, unionization, and labor market flexibility, among others. Estonia, renowned for its advanced digital government, is an ideal case to explore. This leads us to the third research question (RQ3): What institutional configurations have facilitated the adoption of Digital Government in Estonia, and how have these developments affected the organization of work in Estonian public organizations?

By investigating the influence of digitalization on the European public sector workforce, we can provide valuable insights that inform the development of policies and strategies to support the ongoing adaptation and success of public sector employees in the digital age. This research will contribute to the existing body of knowledge on the relationship between technology and the workforce and help policymakers, public sector leaders, and other stakeholders better understand the challenges and opportunities presented by digital transformation in the public sector.

2. Research problem and objectives of the dissertation

This dissertation aims to explore the effects of digitalization in the European public sector workforce by using different methodological styles and levels of analysis following a "James Bond" approach to the research strategy or the combination of diverse methods for inquiry to explore a social phenomenon, as cleverly suggested in the literature.

> *"[…] consciously embraced what might be dubbed a 'James Bond' approach to methodology in the sense of exploring the subject of public service performance by using most (if not quite all) of the range of methodological gadgets available to social scientists, from ethnography to data mining, rather than putting all the emphasis on any one 'killer' method. […] Of course numerous important things have changed in the research environment over the past half-century, both for social science in general and for public management in particular, and those changes are reflected in this special issue. One is the modern information revolution, which opens up new research subjects and new ways of doing research (for example new methods of studying organizations through analysis of their websites, the analysis of e-government or of digital-era governance in general), and which has opened up new ways of performing traditional kinds of analysis, such as blogging as a means of gathering information and reactions from a range of viewpoints.*" (Hood, 2011, p. 322).

Digital government research has emerged as a multi-disciplinary field of study in the intersection of public administration, political science, information systems, economics, computer science, innovation studies, and others that explore the modernization and optimization of government functions via information and communication technologies (Scholl, 2021). The multi-disciplinary nature of this field of inquiry provides a rich theoretical and methodological milieu reflected in the research design of the different chapters of this dissertation.

Conceptual developments have considered the success factors of digital government initiatives from both the supply and demand side. However, given the intrinsic complexity associated with the public sector, a more elaborate discussion is found in the design and use literature that incorporates analytical dimensions such as power, ideology, innovation, and

institutional change in the study of how novel technologies affect the organization of work (Bailey & Barley, 2020). This conceptual evolution is relevant to illustrating the importance of institutional configurations in providing government services.

Understanding the effects of technological change in public sector occupations may serve a two-fold purpose: identifying potential risks associated with automation (job losses and inequality, among others). On the other hand, the effects of technological change may bring benefits to society (increased efficiency, lower operational costs, reduced working hours, etc.); thus, it is pivotal to identify potential opportunities in public policymaking.

3. Data management principles of the project

This dissertation explores quantitative and qualitative research methodologies to accomplish its objectives, ensuring a comprehensive and multi-faceted understanding of the subject matter.

In line with contemporary research practices, there is an increasing emphasis on the need for reproducibility and transparency in academic investigations. This is particularly important in an era where data is abundant, and its management is critical to the integrity and validity of research outcomes. This dissertation, aware of this evolving landscape, has adopted practices that prioritize these principles, ensuring that the research process follows a reproducible workflow to achieve its objectives to the most possible extent.

The dissertation also utilizes a GitHub repository for version control services. GitHub is a widely recognized platform that allows for efficient tracking and management of project changes, making it an invaluable tool for maintaining the transparency and reproducibility of the research process (Beckman et al., 2021; Blischak et al., 2016). Using GitHub, the research ensures that all project iterations are documented and accessible, allowing for a clear audit trail of the research process. Furthermore, the dissertation employed automated transcription services for the interviews conducted as part of the qualitative analysis. This enhances the efficiency of the data collection process.

This dissertation represents a forward-thinking approach to doctoral-level research in the digital age. By adopting practices prioritizing data acquisition and management and

leveraging digital tools and platforms, the study ensures that it adheres to the contemporary imperatives of reproducibility and transparency. This enhances the integrity and validity of the research outcomes and sets a precedent for future research in the field.

4. Structure of the doctoral thesis

Following this introductory section, the research journey commences in Chapter 2 with a systematic and meticulous analysis of an extensive corpus of text data sourced from the Digital Government Reference Library. This library is a rich knowledge repository containing a wealth of information about digital government research. The analytical tool employed in this phase is Structural Topic Modeling (STM), an advanced unsupervised machine-learning technique. STM is particularly adept at handling large volumes of text data, enabling the research to delve deep into the literature, identify prevalent themes, map the evolution of these themes over time, and uncover key research topics in the field. This rigorous analysis of existing literature forms the bedrock of the research project, setting the stage for the subsequent phases.

In Chapter 3, the research project shifts gears to quantitative exploration, employing panel data to probe the relationship between digitalization and public employment indicators. This research phase focuses on 20 European countries, providing a broad and diverse landscape for the investigation. The use of panel data allows for the examination of changes over time and across different contexts, offering valuable insights into the impacts of digitalization on the public sector workforce across various European nations. This quantitative analysis enriches the literature review findings, adding empirical evidence to the theoretical insights gleaned from the STM analysis.

In the final phase of the research project, Chapter 4 transitions into a qualitative exploration, focusing on the case of Estonia, a country renowned for its advanced digitalization and e-government metrics. This phase involves conducting in-depth interviews with subject matter experts who have firsthand experience with the Estonian e-government system. These experts include private contractors, government employees, and elected officials, each offering unique perspectives on the effects of advanced digitalization on the public sector workforce. In addition to these interviews, the research also involves a thorough

analysis of secondary sources to further enrich the Estonian case's understanding. This qualitative analysis allows for a nuanced understanding of the impacts of digitalization, considering the complex socio-political and economic factors at play. In summary, this research project is a comprehensive exploration of the relationship between digitalization and the public sector workforce, employing a blend of methodologies to ensure a holistic understanding of the topic.

Chapter 5, the concluding segment of this dissertation, is dedicated to encapsulating the primary discoveries unearthed throughout this scholarly investigation. It provides a comprehensive and multifaceted synopsis of exploring the intricate relationship between digitalization and the public sector workforce within the European context. This involves a thorough reflection on the implications of these findings, their alignment or divergence from existing literature, and their potential impact on policy and practice within the public sector.

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CHAPTER II - UNVEILING PATTERNS IN DIGITAL GOVERNMENT RESEARCH: A STRUCTURAL TOPIC MODELING APPROACH FOR LITERATURE REVIEW

Abstract

The exponential growth in research output in most fields of knowledge is both a challenge and an opportunity for researchers to apply new computational techniques for scientific inquiry. Digital Government Research (DGR) is a vibrant multidisciplinary field of research at the intellectual crossroads of a wide variety of established academic fields and disciplines such as information systems, public administration, political science, economics, and innovation studies, among others, thus making it the optimal "arena" to pursue this line of inquiry of exploring the relationship between digitalization and the public sector workforce. Structural Topic Modeling is a technique that allows for the systematic analysis of large quantities of text data, enabling researchers to perform evidence synthesis on the bibliographic sample considered, map the scientific discipline under review, explore the thematic evolution over time, and identify and quantify the prevalence of various topics in a selected corpus, thus helping to detect promising areas for further research. This chapter applies a Structural Topic Model (STM), an unsupervised machine-learning technique with the purpose of classification and discovery of scientific topics in a corpus containing a selection of bibliographic records collected and curated in the Digital Government Reference Library version 17.5 (DGRL), a collection of over 16,500 documents, including journal articles, conference proceedings, book chapters. For this dissertation, we trained and tested a structural topic model to scrutinize over 6,600 abstract texts from journal articles to estimate, report, and visualize the latent topics in this subset of the Digital Government Reference Library. This study marks the first attempt to employ unsupervised machine learning techniques in a Digital Government Research corpus. By leveraging Structural Topic Modeling in our analysis, we uncovered and explored key themes and research topics of interest in Digital Government literature. This has enabled us to generate valuable insights into the intellectual structure of the field over the years, identifying dominant topics in the literature and estimating topics of growing interest, thus helping us identify promising areas of research and further inquiry. Among the thirty topics explored in the held-out data, four are related to automation technologies, such as artificial intelligence, cloud infrastructure, blockchain, and the Internet of Things; all of

them present an increasing topic prevalence over time, meaning that these topics are growing in scholarly interest in the field. The model also shows one topic containing words related to employment and work. Still, the graphical analysis via the intertopic distance map reveals no topic content overlap between the topics related to automation technologies and the topic related to labor and employment in the public sector. Thus indicating a relatively new and promising subfield in the extant literature and opening an opportunity to explore the relationship between automation technologies and the public sector workforce.

Keywords: digital government research, topic modeling, structural topic modeling, literature review, text mining, machine learning, text classification, bag-of-words models

1. Introduction

Contemporary trends in global scientific output showcase a swift and sustained surge in the production of immense quantities of unstructured data, primarily in the form of digitized text. This wealth of content presents researchers with the challenging task of systematically, efficiently, and reproducibly exploring and adopting innovative methodological approaches and techniques to examine massive volumes of scientific publications. As the accumulation of bibliographic information continues to outpace traditional methods for processing research output, there is a growing need to incorporate computational-assisted approaches for science mapping and evidence synthesis. Computational approaches to conducting a literature review allow researchers to examine a larger quantity of scholarly publications to perform a literature review in a systematic and reproducible manner and to explore the intellectual structure or the main ideas, theories, subfields, concepts, and their connections evidenced in the bibliographic data which can be used to understand the content and context of the documents in a corpus (Köseoglu, 2020), perform the automated classification of textual data and assist scholars in research tasks such as discovery, measurement, prediction, and causal inference.

Digital Government is a multidisciplinary field of research at the intellectual crossroads of well-established disciplines such as information science, computer science, organization science, sociology, public administration, and political science (Scholl, 2021). This flourishing research

domain benefits from contributions from disciplines with great diversity in research interests and methodologies for inquiry, thus enriching the field with many perspectives and approaches. However, this interdisciplinary nature also presents specific challenges, particularly concerning the development of native theoretical frameworks. The area of Digital Government tends to rely heavily on theories, frameworks, and conceptualizations borrowed from related disciplines (Bannister & Connolly, 2015). This reliance raises questions regarding the need for the field to develop its distinct theoretical foundations to understand better and address the unique complexities and nuances associated with the academic exploration of digital government.

The increasing global research output in most areas of knowledge entails the need for the development and application of cutting-edge computational tools and techniques to harness the opportunities and challenges of the abundance of bibliographic data, work with larger datasets, and to be able to perform new types of analysis benefiting from advances in natural language processing, machine learning, and network analysis. These advanced methodologies enable researchers to sift through vast literature efficiently, identify key themes and trends, and draw meaningful insights from complex data sets and new techniques. Furthermore, these computational approaches have the potential to enhance the transparency and reproducibility of research synthesis, thereby improving the overall rigor and validity of scientific inquiry.

Embracing computational-assisted approaches facilitates the efficient analysis of large-scale research output and fosters interdisciplinary collaboration and knowledge exchange among researchers from diverse fields. By leveraging the power of advanced computational tools, scholars can explore the intricate connections between research domains, uncover hidden patterns, and ultimately contribute to a more comprehensive and holistic understanding of the rapidly evolving scientific landscape of Digital Government Research. Studies in the history of science have revealed a relatively consistent growth pattern in the volume of scientific publications over time. This exponential increase corresponds to a doubling in scientific output approximately every 17 years (Bornmann et al., 2021). Various factors may be contributing to this remarkable expansion. One possible explanation is the substantial increase in resources dedicated to global scientific endeavors, resulting in an enhanced capacity to communicate and disseminate scientific findings via publications. Another factor that may influence the proliferation of scientific publications is the phenomenon known as "salami slicing" or "salami publishing." This practice involves dividing a single research study into smaller parts, each published separately, to maximize the number of

publications generated from a single body of work. This approach, while potentially beneficial for individual researchers seeking to bolster their publication records, has led to overall inflation in the number of scientific articles, which can make it more challenging for researchers to navigate the ever-growing body of literature (Bornmann & Daniel, 2007; Bornmann & Mutz, 2015).

The rapid growth of scientific publications has positive and negative implications for the scientific community. On the one hand, this proliferation of research output reflects the increasing global investment in science and the enhanced capacity for knowledge production and dissemination. On the other hand, it presents unique challenges for researchers attempting to stay abreast of the latest developments in their field, necessitating innovative strategies and tools for efficiently and effectively managing and synthesizing the vast quantities of available information. In this context, embracing computational approaches, such as text mining, topic modeling, and artificial intelligence, becomes crucial for researchers to effectively navigate the rapidly expanding landscape of scientific literature, identify relevant findings, and synthesize knowledge across diverse disciplines.

The dawn of computerization and digitalization has brought about profound changes across various facets of contemporary life, with scientific research being no exception. Digitalization has significantly reshaped the design and execution of research, leading to the creation and increased accessibility of burgeoning data sets. These voluminous data collections necessitate deploying robust computational methods and sophisticated tools to manage and interpret their information effectively (Meyer & Schroeder, 2015).

Unsupervised machine learning techniques for text analysis are examples of how digitalization transforms how academic research is organized and conducted. In topic modeling, unsupervised machine learning refers to discovering hidden patterns or structures (topics) within a dataset (the corpus of text) without prior knowledge or labels. The algorithm is not guided by a predefined set of categories or topics; instead, it independently identifies patterns based on the distribution and co-occurrence of words across the documents. Unsupervised learning in topic modeling is beneficial for exploratory analysis of large text corpora, as it allows researchers to uncover underlying thematic structures without the need for extensive manual annotation or predefined categories.

These techniques can be applied across a broad spectrum of disciplines to scrutinize databases, repositories, and corpora, thereby expanding the methodological toolkit of researchers and providing unprecedented opportunities to delve into vast data reservoirs. Research synthesis is a pivotal component of the literature review process and includes various tools and frameworks examining evidence and influence through content and performance analysis. Topic modeling allows for the exploration of the desired corpus of scientific knowledge in a systematical manner, enabling scholars to gain insights into the conceptual structure, themes, and debates within the field, permitting the review of more significant amounts of papers and relevant documents in a faster and reproducible way. This understanding facilitates the identification of trends in the extant literature and potential areas ripe for further research. Literature reviews are essential tasks but traditionally labor-intensive, time-consuming, and limited in scope due to the constraints of manual methods (Antons et al., 2020; Asmussen & Møller, 2019).

Despite the potential of computer-assisted text analysis, it is not intended to replace human intervention. Instead, it "augments our reading ability" (Grimmer et al., 2022), enhancing the efficiency and breadth of literature review processes while maintaining the invaluable role of human judgment. Indeed, human evaluation and validation remain crucial for interpreting and contextualizing the results generated by these computational models (Barberá et al., 2021). The confluence of machine learning techniques and human expertise paves the way for a more comprehensive, efficient, and insightful exploration of the ever-expanding corpus of scientific literature. The harnessing of computational methods for research synthesis has enabled researchers to generate valuable insights into the intellectual structure of the field over the years, identifying dominant topics in the literature and estimating topics of growing interest, thus helping us identify promising areas of research and further inquiry.

In addition, text-based techniques and topic models have become increasingly popular among scholars examining the intersection between emerging technologies and labor markets, such as exploring the effects of robots and other related labor-saving technologies (Montobbio et al., 2022), the analysis of patent contents to estimate the degree of technological change and the potential for labor displacement (Kogan et al., 2019), and, the creation of thematic dictionaries to explore job-related textual data a gig economy context (Bucher et al., 2021; Waldkirch et al., 2021). These studies exemplify the power of computational techniques in shedding light on the complex

dynamics of digitalization within the labor market, offering valuable insights for both academia and policymaking.

Conceptual developments in Digital Government Research have considered the success factors of digital government initiatives from both the supply and demand sides. However, given the intrinsic complexity associated with the intricacies of public sector operations, such as multiple stakeholder interests, bureaucratic structures, and regulatory constraints, among others, a more elaborate discussion is found in the design and use of technology literature that incorporates analytic dimensions such as power, ideology, innovation, and institutional change in the study of how novel technologies affect the organization of work (Bailey & Barley, 2020). Thus, the interplay between digitalization and work is intricate and multifaceted. Its impacts manifest differently across organizations, industries, and employee groups, underscoring the complexity of the digitalization process (Doellgast & Wagner, 2022). The global health emergency in early 2020 acted as a catalyst, promoting a newfound awareness and increasing research interest in the subject matter (Dingel & Neiman, 2020; Faraj et al., 2021; Leonardi et al., 2021; Mazzucato & Kattel, 2020; Nagel, 2020).

Consequently, it is relevant and timely to delve deeper into the effects of automation technologies, particularly digitalization, within public organizations. This exploration is not merely an academic exercise but a crucial step in preparing for and navigating the future of public service. Digitalization, characterized by deploying various digital technologies to transform services and operations, is increasingly permeating the public sector. It reshapes how public organizations function, alters traditional workflows and introduces new service delivery paradigms. As such, the impact of this digital transformation on the public sector workforce is a topic of significant importance that warrants further investigation.

The public sector is also considered one of the largest adopters and users of Information and Communication Technologies (ICT) and performs a vital role in creating and governance enormous amounts of data (Guenduez et al., 2020; Lofgren & Webster, 2020). Historically, governments have developed the required information infrastructure to manage data-intensive operations such as population and property registries, tax collection, and medical records. The pervasive deployment and use of digital technologies, digital platforms, and digital infrastructures

have accelerated the rate of new data creation, thus transforming the operations of firms and public organizations with profound implications for the organization of work (Nambisan et al., 2019).

The implications of digitalization for the public sector workforce are multifaceted, affecting job roles, skills requirements, and employment structures. Understanding these implications can inform policy decisions, guide workforce development strategies, and ensure that public sector employees are equipped to thrive in an increasingly digital environment. Therefore, an in-depth study into the effects of digitalization within public organizations is not only timely but also essential in the context of a rapidly evolving technological landscape.

The study of the relationship between modern technologies and the quality and quantity of labor has been on the research agenda of diverse disciplines and academic fields, such as economics (Dosi et al., 2021; Evangelista & Savona, 2003; Fernández-Macías & Bisello, 2022), industrial relations (Doellgast & Wagner, 2022), information systems (Klein & Watson-Manheim, 2021), and organization studies (Barley, 2020), primarily focused in the private sector from advanced democracies. Technological change is an extensive term that may include many ICT-enabled applications for automation, digitalization, and robotization. Our attention is directed at the digitalization of government. Still, despite the momentum in digital government research, one aspect that remains under-explored is the empirical assessment of the effects of digital technologies on the public sector workforce (Plesner et al., 2018).

The composition of the European public sector workforce is very heterogeneous in scale and scope among diverse jurisdictions. Public sector organizations rank high globally among the largest employers in the form of armies and other defense-related operations, State-Owned Enterprises (SOE), and healthcare providers, to name a few. The ‘industries’ in which public organizations operate are very diversified and have distinct degrees of technological sophistication and mixed levels of interaction with citizens and firms. The public sector commands a large, diverse, highly educated workforce.

The reported impact of digitalization on the organization of work is diverse (Barley & Kunda, 2001); it may automate work, create or eliminate jobs, and deskill or reskill workers but also have little or negligible impact whatsoever on labor. Digital government as a research field is in a consolidation phase, allowing for exploring promising subfields for further inquiry. Digital technologies and the novel design of public services may facilitate a more intricate division of

labor into smaller components (tasks), reconfiguring the workflow of public services, fostering new ways for multi-actor co-production (Bryson et al., 2016), promoting the implementation of self-service solutions and facilitating scenarios for the co-production of public services (Scupola & Mergel, 2021), turning each citizen and user into "*his or her administrator, caseworker and bureaucrat*" (Schou & Hjelholt, 2018), and possibly creating detrimental effects such as administrative burden for citizens (Madsen et al., 2021).

These developments enabled by the implementation of digital technologies in public organizations are changing the interaction between citizens and public officials, turning it into a technology-mediated public encounter (Lindgren et al., 2019), introducing changes in the organization of work in terms of task redundancies and the creation of new occupations, to cope with an increasingly digitalized public sector. The argumentative arc presented above sparks the discussion of automation in a public sector context as an emerging topic of interest in the extant literature (Andersson et al., 2021; Engin & Treleaven, 2019; Lloyd & Payne, 2021).

Specifically, this chapter aims to address the following research questions:

RQ1: What are the dominant topics of scholarly interest in the selected corpus, the Digital Government Research Library?

RQ2: What does the application of a topic modeling reveal on the linkage between digitalization and the organization of work in the extant literature (corpus) on Digital Government?

RQ3: What research areas are deemed promising for further research by examining their trends and coverage over time?

This study represents the first attempt to apply structural topic modeling to a corpus in the Digital Government Research field. Textual data is often expensive to produce, gather, and collate (Grimmer et al., 2022). The content of previous versions of this data set has been utilized as primary or secondary sources for exploring the Digital Government field via bibliometrics and other systematic reviews. The computational techniques applied in this study are deemed an essential methodological step towards data-driven, reproducible methods for reviewing the literature in any given field and contributing to the overall research question of this dissertation, asking if digitalization is a labor-saving technology in the public sector workforce.

Section 2 of this document provides a quick literature review of the methods pursued in this chapter, arguing for the implementation of computational and programmatic techniques in the study of the extant literature. Section 3 describes the research design and methods used for this chapter's elaboration; section 4 discusses the findings of implementing a topic model in the test set of the DGRL v. 17.5 corpus; and section 5 provides comments and conclusions on the current analytical exercise.

2. Topic Modeling: An advanced method to conduct a Literature Review

Traditional, non-computational approaches to exploring, reviewing, and analyzing the literature of any scientific domain are considered labor-intensive and prone to biases (Nakagawa et al., 2019). Quantitative research syntheses techniques, such as topic models, bibliometrics, and other computer-assisted text mining, offer an opportunity to analyze more prominent quantities of documents. These methods significantly advance the "research fronts" in interdisciplinary fields, including Digital Government (Tanskanen et al., 2017). Computational tools and techniques, initially developed in the realm of computer science, have been repurposed across a variety of disciplines. These computational methods have enabled social scientists to leverage Natural Language Processing (NLP) applications for classification tasks involving substantial scientific corpora and textual data. Topic modeling techniques, a subdivision of machine learning and NLP, facilitate the automated classification of vast quantities of text data. These powerful tools have analyzed bibliographic content across various research fields and academic disciplines.

Topic modeling analysis has been applied to bibliographic data spanning years, even decades, in diverse scientific realms and academic disciplines such as statistics (Battisti et al., 2015), information management (Sharma et al., 2021), economics (Ambrosino et al., 2018), cliometrics (Wehrheim, 2019), innovation research (Antons et al., 2020; Antons & Breidbach, 2017), management (Hannigan et al., 2019) and more recently, artificial intelligence (Dwivedi et al., 2023).

The scope of these analyses can be very, *very large*; Ambrosino *et. al.* studied the evolution in the thematic structure of the economics discipline by applying a topic model to the full texts of articles published in 188 journals in the JSTOR database from 1845 to 2013 for a total of 250,846 documents or very, *very specific*, exploring a corpus of full-text articles (n= 1,008) from a single

top-ranking publication in innovation research (Antons et al., 2016), or to delve on a topic of growing research interest such as Artificial Intelligence by analyzing a corpus of documents (n= 608) created by concatenating strings of words from title, abstract and keywords from articles in a top ranking journal in Business and Management (Dwivedi et al., 2023).

The application of topic modeling techniques in diverse samples of bibliographic information for various disciplines underscores their utility in extracting valuable insights from large volumes of textual data. By allowing researchers to navigate and comprehend extensive document collections efficiently, these methods enrich the research process, uncover hidden thematic structures, and facilitate the identification of emerging trends and patterns. As such, topic modeling techniques constitute an invaluable asset in the multidisciplinary endeavor to understand and shape the dynamics of digital government.

The unstructured text has become one of the most prevalent data types in the current “data deluge.” Text is a key data source in organizational research as organizations publish content on their websites, social media, and other searchable repositories (Kobayashi et al., 2017). Text analysis or text mining is not necessarily new; however, the digitalization of everyday life has facilitated the creation, storage, and analysis of enormous quantities of data in text format. Text mining techniques have remained “disconnected among fields” (Banks et al., 2018).

Latent Dirichlet Allocation (LDA) is a generative probabilistic model widely used in natural language processing and machine learning for topic modeling. The fundamental assumption of LDA is that each document within a corpus is a mixture of a certain number of topics, and each word within the document is attributable to one of these topics (Blei et al., 2003). The "latent" aspect refers to the hidden or unobserved groups (topics) the model seeks to identify. The "Dirichlet" component of the name refers to the Dirichlet distribution, a probability distribution used in the model to represent the per-document topic distributions and per-topic word distributions. The allocation process involves inferring these distributions, ultimately providing a probabilistic topic assignment for each word in each document. LDA is a powerful tool for discovering abstract topics within large text corpora, enabling the summarization, exploration, and organization of large datasets. Latent Dirichlet Allocation is a state-of-the-art, simplest, and most used method for topic modeling (Asmussen & Møller, 2019). Though LDA models are becoming widely used in social science, these techniques are not infallible and require rigorous validation

and human interpretability (Maier et al., 2018); if not, it could be as factual as “reading tea leaves” as eloquently put by scholars in a pertinent critique and commentary to this method’s limitations (Chang et al., 2009). For a robust analysis, it is advised to take an iterative approach to build, compute, critique, and rebuild topic models (Blei, 2014).

Even though these techniques originated in the computer science field and at first sight may seem arcane to newcomers, there has been substantial progress in other research areas towards facilitating the adoption of this powerful computational tool by lowering the technical barriers, creating agreed-upon workflows for modeling and visualization, and the development of relatively accessible software packages in open-source statistical software like R and Python (Benoit et al., 2018; Rehurek & Sojka, 2010; Roberts et al., 2019).

Structural Topic Modeling is a conceptual and technical evolution of the typical topic modeling approach by incorporating the estimation of topic prevalence using covariates found in the metadata of the corpus (Roberts et al., 2016). Applications of this method to bibliographic data have estimated the role of covariates such as temporal and geographic information, opening new avenues for statistical interpretation in the analysis of the dissertation titles in economics and chemistry in East and West Germany before and after the German reunification (Rehs, 2020).

As advised by (Barberá et al., 2021), there are “*consequential decisions*” in the methodological choices of automated text classification and the fact that human validation is a critical component of text as data methods. The selection of a corpus is deemed a crucial decision prone to four types of bias: *resource bias, incentive bias, medium bias, and retrieval bias; these* selection biases are well-acknowledged in the text as data literature (Grimmer et al., 2022).

The selection of a corpus is deemed a crucial decision that can be prone to four types of bias: resource bias, incentive bias, medium bias, and retrieval bias; these selection biases are well-acknowledged in the text as data literature. Resource Bias refers to the bias introduced by the uneven distribution or availability of resources. For example, suppose the corpus of documents used in topic modeling is primarily from one specific source or disproportionately represents a particular viewpoint or culture. In that case, the topics identified by the model may be skewed toward that source's perspectives and language use. Incentive Bias occurs when the incentives of the authors or publishers of the texts in the corpus influence the topics written about or how they are presented. For example, in analyzing news content, if a particular political party funds a news

outlet, the articles they produce might consistently favor that party's stance, thus influencing the topics and sentiment of the corpus.

Medium bias refers to the influence that the form or medium of the text can have on the topics discussed or the way they are presented. Different mediums have different conventions, styles, and limitations. For example, academic journals might have various dominant topics or methods of discussing those topics compared to blog posts or tweets. If the corpus includes texts from multiple mediums, this could affect the topics the model identifies. The last one is Retrieval Bias; this bias relates to how data or information is retrieved for the corpus. The methods used to collect or select the texts for the corpus can introduce bias. For example, if a search engine is used to compose articles on a particular topic, the search algorithm could influence the results, which might favor specific sources or viewpoints. This can result in a skewed representation of the topic in the corpus.

These selection biases can significantly impact the results of text-as-data analyses, and researchers need to be aware of them and take steps to mitigate their effects. It may be probable that the Digital Government Research Library version 17.5 has omitted necessary research not included in this collection. As all decisions concerning text as data methodologies are “consequential,” we aim to make our workflow as reproducible as possible by documenting all the choices in the scripts associated with this document in a GitHub repository.

Prior investigations of the Digital Government Reference Library have employed bibliometric and scientometric approaches to uncover the thematic evolution of the field (Alcaide–Muñoz et al., 2017). These studies have also identified the domain's most influential journals, conferences, and leading scholars (Scholl, 2021). Moreover, this data set has been utilized to conduct a systematic review of the impacts of e-government from a public value perspective (MacLean & Titah, 2021). To perform a robust and thorough literature review, it is advised and considered a best research practice to accumulate a "complete census" of relevant literature while adhering to a concept-centric framework (Webster & Watson, 2002). This chapter explores and analyzes the corpus using unsupervised topic modeling methods, which are well-suited for uncovering hidden patterns and themes within large volumes of textual data.

Probabilistic topic models represent a form of unsupervised machine learning that facilitates the exploration and analysis of extensive collections of documents, commonly referred

to as corpora. These models enable the automated classification of large volumes of textual data, significantly aiding scholars in research tasks such as discovery, measurement, prediction, and causal inference. Topic modeling offers a scalable approach to handling larger bibliographic data sets, allowing for extracting relevant concepts from sizable corpora with increased efficiency. By applying topic modeling techniques to the DGRL corpus, this study seeks to advance our understanding of the multifaceted field of Digital Government Research and uncover novel insights and trends within the domain.

By employing unsupervised topic modeling techniques, this research aims to expand the existing literature by offering a more comprehensive understanding of the Digital Government field and its evolution. This approach will enable scholars to identify key trends, emerging research areas, and potential avenues for future investigation, further enriching the body of knowledge within this multidisciplinary domain. The optimal number of topics (k) is unknown, and the researcher should select this parameter; there is technically not a “right number of topics” in general; a low number of topics is used for an overview. Instead, more topics are used for a more granular corpus analysis under exploration.

Text data is incredibly diverse in length and content. Social media posts, political speeches, press releases, and customer reviews are the usual targets of this kind of analysis. For researchers exploring bibliographic data, the unit of study can be the document's title, the abstract, or the whole text of the documents in the corpus. Text data can be coerced into a structure for processing using the bag of words approach. The bag of words assumption means that the order of words within each document is ignored, and the thematic structure of the document can be inferred by the frequency distribution of observations (Maier et al., 2018).

Scholars investigating the implications of labor-saving technologies and digital work have successfully employed similar techniques and text as data methods (Bucher et al., 2021; Montobbio et al., 2022). This pioneering work has broadened the methodological toolbox available to researchers in this area, providing innovative approaches to understanding complex data sets. These studies offer more than just a set of new tools; they also inspire and pave the way for analogous investigations into the impact of technological transformations within the public sector. The potential for these methods to reveal nuanced insights is immense, especially when exploring the often complex and multifaceted effects of technological change in a public sector context. As

the public sector grapples with the challenges and opportunities of digitalization, these advanced analytical techniques can offer a deeper understanding of the underlying trends, dynamics, and patterns that emerge from the academic literature. However, important caveats and limitations should be considered, including the potential selection biases regarding accessibility, medium, and retrieval of the corpus under scrutiny.

3. Research design and methods

The Digital Government Research Library version 17.5 (updated in December of 2021) is a large, curated repository of publications contributing to the Digital Government Research (DGR); it contains more than 16,500 references among its records. The most prevalent types of documents are conference papers (33.2%) and journal articles (50%). The inclusion criteria of the DGRL are to have passed academic peer review, to be published in an academic journal, and to be published in English (Scholl, 2021). The most updated library version can be downloaded from the website "The Digital Government Reference Library" https://faculty.washington.edu/jscholl/dgrl/index.php.

Table 1. Types of documents in the Corpus

Document Type	Number of Documents
Journal Article	8278
conference paper	5492
book sections	2083
book	636
report	33
thesis	3
magazine article	2
manuscript	1
webpage	1

Source: Digital Government Research Library Version 17.5

The download package contains three types of bibliographic files: BibTeX, RIS, and ENL (EndNote). The data has many missing values in its raw and unprocessed form, primarily clustered in metadata not considered relevant for the analysis. By exploring the bibliographic formats,

BibTeX, RIS, and ENL files, we noticed that the data sets had many missing data and that some information was available in one file type but not another. The script's initial data wrangling and transformation documents the steps and choices made to the initial data set. The unique digital object identifier (DOI) was an exact key to merge the data sets and a "quality control" step to retain documents with valid DOIs.

The following variables have been deemed of interest for the analysis: type of reference (conference paper or journal article), year of publication, author, document title, publication title, and the presence of an abstract. Text is a type of unstructured data that requires meticulous processing before using it. For replicability purposes, the script for the whole data processing, including the R functions and packages used, is available for revision and consists of four scripts with detailed documentation on the treatment of data. The scripts for cleaning and wrangling the data, the application of stemming algorithms, and other tokenization decisions, and the proportion between train and test set and other parameters are publicly available in the scripts and documentation of the GitHub repository titled "**topic_model**" for this project: https://bit.ly/3pINI4I.

Text is a type of unstructured data that requires intensive processing to work with. This means that before being able to create and analyze a corpus object containing the information deemed of interest, "consequential decisions" must be made. It is considered a best practice to use version control systems in all the analysis phases for efficiency, replicability, and transparency.

The bag of words approach deliberately ignores the syntax or structure of the text; creating a bag of words is known as tokenizing. Additional treatment of text includes eliminating punctuation, transforming each word to lowercase, and, in some cases, stemming, which is a way to reduce a word to its stem or root to reduce the sparsity of the resulting matrices. Even though these steps may seem difficult to understand at first, the publication of open software packages, the availability of vast documentation, tutorials, and vibrant online knowledge communities have lowered the technical barriers of this powerful computational tool for research.

The next step in pre-processing is the creation of the document-feature matrix[1] containing all the documents and the tokenized text. The usual result is a very sparse matrix. Best practices found in the literature suggest performing dimensionality reduction to the matrix by dropping features with a very low frequency of occurrence and the prevalent features, the most common words in the corpus, given that it is assumed that these ubiquitous words will not contribute to the discovery of the latent structure of the corpus.

Latent Dirichlet Allocation (LDA) is an unsupervised machine learning technique, meaning it does not consider the relationship between words and topics before running the model. Given this, it is considered best practice to divide the data into a training set and a test set to substantiate the robustness of the model. In our methodology, we designate 50% of the corpus for training the model, setting aside the remaining 50% for testing and model validation.

Given that Latent Dirichlet Allocation (LDA) assumes that documents are a mixture of topics and that each word in the document is attributable to one of the document's topics makes it particularly useful in literature reviews to perform: A) Topic identification, LDA can help identify the main themes or topics across a large set of documents, such as academic papers or book chapters. This can be useful for understanding the focus areas in a field of study or within a specific collection of texts. B) Text classification: once topics have been identified, new documents can be classified based on the likelihood of their content belonging to one of those topics. This can help in organizing or categorizing literature for a review. C) Identify trends over time; if the documents in the corpus have timestamps (like publication dates), LDA can be used to analyze trends in topic popularity over time. This could be useful for understanding shifts in research focus or literature themes. D) Document comparison: LDA provides a way to compare documents by representing documents as mixtures of topics. This could be useful for identifying documents like each other in a literature review context. E) Keyword extraction, topic models like LDA can also be used to identify keywords and phrases associated with each topic, which can be helpful for indexing, searching, and summarizing literature. In summary, in the context of a literature review, LDA can help researchers understand the key themes, how they have evolved, and how different documents

[1] In the *quanteda* R package, the Document-Feature Matrix is equivalent to the Document-Term Matrix of alternative text mining software. Features in this context are the individual tokens (single words) from the documents in the corpus.

relate to those themes. This can save significant time and provide a high-level view that would be hard to achieve through manual review.

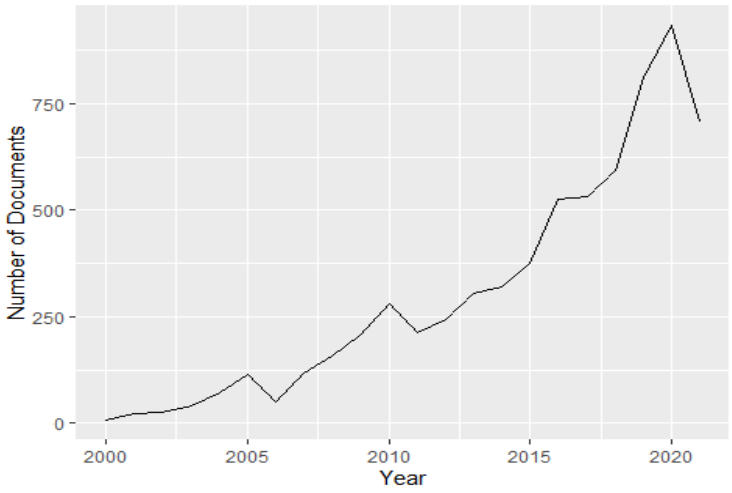
A pivotal decision in applying LDA is determining the optimal number of topics (*k*) to be extracted. This parameter, which the researcher must choose, can significantly influence the outcomes. Importantly, there is no universally "correct number of topics," as this choice is highly contingent upon the specifics of the corpus and the research design (Grimmer & Stewart, 2013). Choosing 'k' involves balancing between capturing sufficient detail and granularity or having a broader literature overview (Asmussen & Møller, 2019). Deciding the number of topics often requires iterative testing and refinement, utilizing various metrics or qualitative evaluations to ascertain the appropriateness of the chosen topic count. In the final analysis, the optimal number of topics will be the one that best enables the model to effectively categorize and interpret the text data, thereby providing meaningful insights into the themes inherent within the corpus.

The evaluation of topic models can be performed through the calculation of goodness of fit statistics and the iterative calibration of the model to increase interpretability via “eyeballing” the topics and their word-probability and human judgment, meaning the implicit knowledge of the researcher on the subject matter of a corpus. A rule of thumb found in the documentation of the ‘stm’ R package states that for small corpora, like the one used for this analysis containing “a few hundred to a few thousand” documents, 5 to 50 topics is “a good place to start, then an iterative calibration of the model is due. In addition, the ‘stm’ R package includes functions for model selection, visualization, and estimation of the effects of covariates in topic prevalence (Roberts et al., 2019).

Four goodness of fit measures are usually considered when exploring the optimal number of topics to apply to a corpus: perplexity, coherence, residuals, and lower bound. The held-out likelihood, also known as perplexity, measures how well the probability model predicts unseen data; a lower number in this measure implies a higher model accuracy. Semantic coherence is maximized when the most probable words in a topic co-occur frequently (Roberts et al., 2014). The lower bound indicator explains the convergence in the iterations of the model; when there is a slight change among iterations, the model is considered converged. As for residuals, this diagnostic measure calculates the sample dispersion; if the number for this value is greater than one (>1), it suggests that the number of topics is set too low (Taddy, 2011).

After the initial data wrangling, the relevant data for 6682 journal articles, or approximately 80.7% of the total number of articles in the DGRL v17.5, is further processed to create a corpus, the initial step toward a topic model. Documents published before 2000 were dropped from further analysis due to their negligible quantity; a single observation from 2022 reduced the corpus slightly to 6664 papers. The visualization of the publication trend demonstrates an incipient increase in journal articles after 2000 and a steep increase from the beginning of the 2010 decade to the present. The decline observed in 2021 in research output for topics unrelated to the health crisis could likely be attributed to the impact of the COVID-19 pandemic. The pandemic has influenced various facets of research, including scholar mobility, resource availability, and the capacity to carry out studies and disseminate findings.

Figure 1. Number of Documents year by year in the analyzed sample



Source: DGRL Corpus of Journal Articles 2000-2021.

The subsequent step is the creation of a corpus object. A second script describes the phase of pre-processing related to preparing the unstructured text data into a format usable for analysis. This phase includes tokenization, removal of stop words, symbols, and special characters, and conversion to lowercase (Maier et al., 2018). There are several software packages for text analysis, mining, and visualization. Our choice for pre-processing was conducted in R statistical software using the functions of the '*Quanteda'* R package (Benoit et al., 2018). After several iterations, we deemed using a stemming algorithm to aid the dimensionality reduction in the matrices by cutting words to their root form.

As suggested by (Webster & Watson, 2002), a complete review covers the relevant literature, and it is not limited by a single research methodology, set of journals, or geographic region; topic models contribute to expanding the options available to researchers and amplify the scope and reach of their inquiries. The Table 2 presents the top 30 publication titles (journal names) in the corpus ranked by the number of documents in the corpus, the rank in the Scimago Journal Rank system, Best Quartile, h-index, and country.

Table 2. Top 30 Journals in the Corpus by Number of Documents

Publication Title	Number of Documents in Corpus	SJR 2022	SJR Best Quartile	H-index	Country
Government Information Quarterly	777	2,321	Q1	123	United Kingdom
Electronic Government, an International Journal	260	0,351	Q3	37	United Kingdom
Transforming Government: People, Process and Policy	255	0,585	Q2	43	United Kingdom
Journal of Information Technology and Politics	253	0,992	Q1	46	United States
International Journal of Electronic Government Research	229	0,272	Q3	33	United States
Information Polity	201	0,501	Q2	40	Netherlands
International Journal of Electronic Governance	198	0,321	Q2	20	Switzerland
Information Technology for Development	123	1,196	Q1	46	United Kingdom
International Journal of Public	118	0,181	Q3	5	United States

Publication Title	Number of Documents in Corpus	SJR 2022	SJR Best Quartile	H-index	Country
Administration in the Digital Age					
Social Science Computer Review	107	1,662	Q1	85	United States
International Journal of Public Administration	98	0,691	Q2	52	United States
Public Administration Review	79	3,311	Q1	163	United Kingdom
Sustainability	77	0,664	Q1	136	Switzerland
International Journal of Information Management	75	4,906	Q1	152	United Kingdom
JeDEM - eJournal of eDemocracy and Open Government	69	0,23	Q3	20	Austria
Digital Government: Research and Practice	52	0,554	Q2	12	United States
Information Communication and Society	48	1,807	Q1	101	United Kingdom
Telematics and Informatics	47	1,878	Q1	93	United Kingdom
Information Development	45	0,559	Q1	34	United Kingdom
Telecommunications Policy	43	1,192	Q1	81	United Kingdom
Comparative E-Government	42	NA	NA	NA	NA
Technological Forecasting and Social Change	39	2,644	Q1	155	United States
American Review of Public Administration	37	1,745	Q1	69	United States

Publication Title	Number of Documents in Corpus	SJR 2022	SJR Best Quartile	H-index	Country
International Review of Administrative Sciences	37	0,993	Q1	65	United Kingdom
Information Systems Frontiers	36	1,424	Q1	79	Netherlands
Administration and Society	34	1,238	Q1	72	United States
Computers in Human Behavior	34	2,464	Q1	226	United Kingdom
Online Information Review	34	0,74	Q1	69	United Kingdom
Public Management Review	34	2,157	Q1	87	United Kingdom
Information Technology & People	33	1,08	Q1	71	United Kingdom

Source: Information from Corpus merged with data from Scimago Journal Rank 2022.

The 30 most represented sources account for more than 53.4% percent of documents under scrutiny, 20 out of the 30 publications occupy the first quartile in their best ranking category, as regards the country, publications from the United Kingdom (15), and the United States (9) dominate the sample, just one publication titled “Comparative E-Government” was not found listed in the Scimago Journal Rank database.

Text-as-data methods are inherently iterative, thus requiring the adoption of suitable workflows and best practices for model calibration and version control systems of its operations; even though stop words are considered language-specific, and Natural Language Processing applications are advancing in sophistication, some stop words are corpus-specific. In the downstream of this process, we found strings with no relevant meaning to the analysis but very prevalent in the corpus, thus the importance of constructing the workflow programmatically in an R environment.

Quanteda, a powerful text analytics package, comes equipped with an efficient pre-processing workflow that offers a variety of valuable features. Among these, it includes functions that enable the discovery of multi-word expressions through collocation analysis. This analysis is particularly advantageous for identifying proper names, along with other significant phrases, that could be pivotal in understanding the underlying context of a textual dataset. In computational linguistics, n-grams refer to contiguous sequences of 'n' items from a given sample of text or speech. They can be unigrams (single words), bigrams (two-word sequences), trigrams (three-word sequences), and so on. The idea is to identify sequences of words that frequently occur together.

N-grams allow researchers to identify common phrases or recurring themes that might indicate the text's overall sentiment or subject matter. Moreover, n-gram analysis can help reveal patterns and trends often missed in single-word frequency analysis, thereby adding depth and richness to the textual data interpretation. Identifying multi-word expressions through collocation analysis and n-gram identification provides researchers with a robust toolset for extracting meaningful insights from large volumes of unstructured text data.

Employing n-grams—a sequence of ‘n’ contiguous items from a text string—offers a multi-fold suite of advantages in content analysis. They provide valuable insights into lexical patterns and structural nuances within textual data, furnishing a robust mechanism for recognizing and assessing prevalent word combinations and linguistic structures. Their utilization enhances the granularity of text classification, sentiment analysis, and language modeling, allowing for the discernment of contextual subtleties and the intricate interrelation of linguistic items, thereby fortifying the predictive accuracy of analytical models.

However, n-grams are not without limitations. Their primary constraints arise from their inability to comprehend semantic relations and capture long-range dependencies between words or phrases, making them prone to misinterpretations of context. Additionally, the high dimensionality and sparsity of n-gram models engender computational challenges and can obscure meaningful relationships amidst numerous non-informative features. Thus, while n-grams serve as pivotal instruments in extracting lexical and syntactical information for content analysis, their utility is delimited by their incapacity for semantic comprehension and susceptibility to morphological and structural variances.

In addition, stemming is a common technique used in natural language processing; it reduces words to their root form, enhancing text analysis efficiency by grouping similar words. Despite this process of simplification, the recognizable clusters of words in the word cloud demonstrate the recurring themes or topics in the data, offering valuable insights into the primary focus of the corpus. Applying a stemming algorithm in the context of topic modeling serves several vital functions to simplify and standardize the text data for more effective analysis, including text normalization, topic coherence, efficiency, and comparability.

Regarding text normalization, stemming reduces words to their root or base form, which helps standardize different forms of the same word. For example, "running," "runs," and "ran" would all be stemmed from "run." This normalization process aids in consolidating similar topics and reducing the dimensionality of the data. In terms of improving topic coherence, stemming can help improve the coherence of the identified topics. Different forms of the same word will be treated as a single entity, making the topics more interpretable. In addition, stemming can make the topic modeling process more efficient by reducing vocabulary size. This can lead to faster computation and lower memory requirements, and finally, stemming can enhance the comparability of documents by ensuring that the same root word is used across different documents, regardless of the specific form of the term used in each document.

The next step in the process is to create a Document-Feature Matrix, which is the method to provide a structure to the text and be able to conduct the quantitative analysis of the corpus. From this step in the process, we gather that the corpus under study contains 6664 documents (abstracts) with their respective metadata and 18749 features (unique tokenized words). This is a very sparse matrix, and the logical step is to conduct two processes for dimensionality reduction: remove very common and very rare words. For the removal of rare words, the parameter was set to retain words with a minimum term frequency of 100; for the most common words, the criteria were to remove words that appear in more than 10% of the documents in the corpus. After these decisions, the number of documents remained the same, and the number of features and vocabulary used for the topic model was reduced to 916. The documented code for these steps can be found on the GitHub page for this project for replicability purposes.

One crucial step before the initial calibration of the model is to split the data between a train and a test set; the model was trained with 50% of the sample. The remaining 50% is used to

apply the model to the unseen data with the calibrated parameters of the model's training. The novelty of the structural topic model is the possibility to include covariates found in the metadata to estimate topic prevalence; for our analysis, the year of publication is a covariate of interest.

Estimating topic models, while complex, is not necessarily the most challenging aspect of working with such models. Indeed, the real work for researchers often comes in interpreting and visualizing the model's output. These tasks demand a deep understanding of the data, model, and topic structures identified by the model. The R 'stm' package, frequently employed in this process, has distinct advantages and disadvantages in visualizing topic models. However, one of its most remarkable strengths is the ability to include covariates in calculating topic prevalence. This feature allows researchers to examine how the distribution of topics can vary based on different conditions or characteristics, thus adding an extra layer of depth to the analysis.

Structural Topic Modeling (STM) represents a significant advancement in topic modeling, enriching the traditional approach by integrating covariates from the corpus metadata into estimating topic prevalence. This innovation allows for a more nuanced understanding of the data by incorporating additional context, such as temporal or geographical information, into the analysis. These covariates can offer vital insights into the distribution and evolution of topics over time or across different regions, thus adding a new layer of richness to interpreting the results. For example, geographical covariates might reveal regional differences in topic prominence, while temporal covariates could help trace the ebb and flow of various themes over time. Analyzing topic prevalence is particularly crucial in identifying burgeoning trends within a corpus. It allows researchers to gauge which themes are gaining traction and which are receding, facilitating the recognition of potential areas of growth and emerging patterns of interest. STM enhances this analysis by contextualizing these trends within specific temporal or geographical parameters by incorporating metadata covariates. For our case, the covariate to estimate topic prevalence is the time variable ‘year’ contained in the metadata of the corpus.

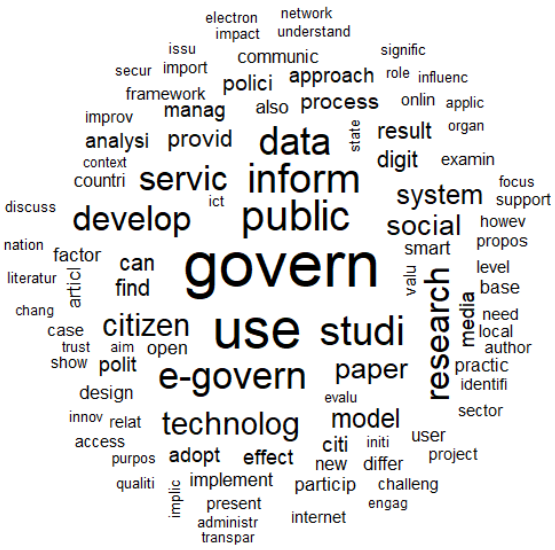
4. Findings

The application of the topic model involved a systematic and reproducible approach, commencing with data preprocessing, which included tokenization removal of stop words and stems, followed by the implementation of the model and culminating in the analysis of the results.

The model's parameters were meticulously calibrated to optimize coherence and interpretability, ensuring the extracted topics were coherent and resonant with the thematic essence of the corpus under analysis. The findings delineated in this section present a brief recapitulation of the methodology, underscoring the procedural nuances and the rationale behind the chosen parameters. Subsequently, each discovered topic is elucidated, illustrating the predominant terms and their prevalence over time.

Figure 2 presents a visual representation, specifically a word cloud, highlighting the top 100 most frequently occurring words within the text corpus currently under examination. Word clouds are a valuable tool in data visualization, enabling viewers to quickly discern the most prevalent terms in a body of text. In this illustration, specific phrases or 'strings' of words stand out noticeably, indicating their prominence within the corpus. This is an interesting observation, especially given the application of a stemming algorithm in our data preprocessing stage.

Figure 2. Top 100 unigrams in the corpus

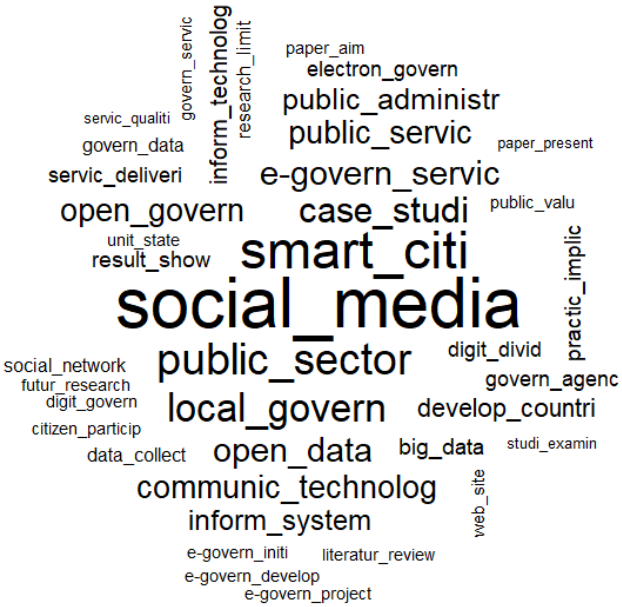


Source: The word cloud was created with the visualization functions of *Quanteda*

Figure 3 visualizes a word cloud, spotlighting the top 40 bigrams extracted from the corpus under study. It is important to note that the processing of this corpus incorporated the application of a stemming algorithm. Consequently, the presented bigrams consist of the words' root forms.

Bigrams, a type of n-gram where n equals 2, are pairs of consecutive words used together in the text. They offer a more nuanced perspective of word usage patterns than individual words, highlighting how words interact and connect within the text. Notably, paired strings of text such as *'social_media*' and *'smart_citi*' are distinctly dominant in this visual display, underscoring their frequency of co-occurrence within the corpus. The most salient bigram is "*social_media,*" implying the centrality of these platforms for digital government scholarship, from the adoption and use by public organizations (Mergel & Bretschneider, 2013) to the role of social media in political campaigns (Karlsen, 2010; Mascheroni & Mattoni, 2013), the regulation of disinformation (Marsden et al., 2020), and the provision of public services (Criado & Villodre, 2021; Tursunbayeva et al., 2017).

Figure 3. Top 40 bigrams in the corpus



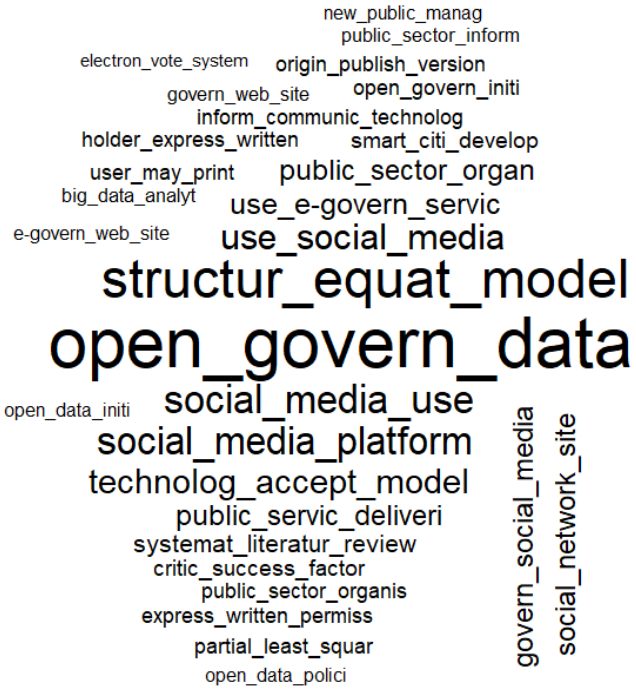
Source: The word cloud was created with the visualization functions of *Quanteda.*

Other salient bigrams include "*smart_citi*," "*local_govern*," and "*open_data*." A closer examination provides hints on methodological aspects; the bigram "*case_studi*" carries a lot of meaning, informing about the frequency of this method in the sample. The ubiquity of the bigram "*public_valu*" for the public value theory shows the important evolution from New Public Management to alternative theoretical frameworks (Panagiotopoulos et al., 2019). For a summary

of the most frequent theoretical frameworks used in Digital Government Research, refer to the work of Bannister and Connolly (2015).

The ubiquity of the word service in bigrams such as "*public_servic*," "*servic_deliveri*," "*servic_qualiti*," and "*govern_servic*" provide a glimpse into government operations, the creation of public services but not necessarily with a service logic as argued by (Cordella & Paletti, 2018). This also suggests the influence of the work by (Vargo & Lusch, 2004) on service-dominant logic and its conceptual evolution, including digital aspects (Barrett et al., 2015), and the adaptation to a public sector context by introducing a "public service logic" (Osborne, 2017), evidencing the rich conceptual roots from the field of service innovation studies that support digital government scholarship.

Figure 4. Top 30 trigrams in the corpus



Source: The word cloud was created with the visualization functions of *Quanteda.*

Figure 4 shows a word cloud visualizing the top 30 trigrams in our corpus of study. Trigrams, a type of n-gram where n equals 3, are sequences of three consecutive words in the text. This text analysis method uncovers more complex linguistic patterns and contextual meanings than individual words or bigrams, illuminating how words interplay and form coherent thoughts within

the textual data. The prevalence of specific trigrams in the word cloud allows one to identify other types of dominant content within the corpus. For instance, recurring trigrams might signify important thematic phrases or common linguistic constructs prevalent in the text. They could even highlight popular opinions, sentiments, or trends embedded in the corpus. In essence, the co-occurrence of these trigrams allows us to delve deeper into the text's content structure. It aids in discerning more about the subtleties of the language used, the potential thematic undercurrents, and the critical discussions happening within the corpus. By highlighting these recurring trigrams, we can gain a more comprehensive understanding of the corpus, paving the way for an intricate, detailed examination of the text's content.

In analyzing the top 30 trigrams within the corpus, one phrase dominates the word cloud: *'open_govern_data.*' This concept is usually linked to the theory of public value. A comprehensive literature review conducted on the public value of e-government concluded that open government data has the potential to enhance several critical public values, including openness, transparency, public participation, effective communication, and collaboration (Twizeyimana & Andersson, 2019), on the other hand, this can be interpreted as the prevalence in use of this type of data for research purposes in the corpus contents. Another prominent trigram is *'structur_equat_model*.' This salient position presents an interesting contrast with the reported over-reliance on qualitative methods in the field of digital government. This is an important finding given the assumption that digital government scholarship tends to rely mostly on qualitative research; the centrality of structural equation modeling in the trigrams cloud hints at a rich methodological toolbox and variety of approaches to the scientific exploration of the field.

Further, the trigram *'partial_least_squar'* provides a subtle clue about the importance of these statistical methodologies within the corpus. Partial Least Squares (PLS) is a method commonly used in structural equation modeling, reinforcing the earlier observation about the possible significance of quantitative analysis in this corpus. The trigram *'technolog_accept_model'* is another significant co-occurrence; this refers to the Technology Acceptance Model, a theory introduced in the pioneering work of (Davis, 1989). It was later adapted to the digital government field (Hung et al., 2006). The model's prominence in the corpus suggests that it might be a primary framework used to understand and predict the acceptance and use of technology within the context of digital governance. Lastly, the trigram *'new_public_manag'* hints at another dominant theme in the corpus. This phrase is linked to the 'New Public Management' paradigm, a managerial approach

widely adopted in the public sector during the late 20th century (O'Flynn, 2007). Its prevalence in the corpus implies that this paradigm is a dominant theoretical framework or lens through which the corpus documents examine and interpret public administration in the digital age.

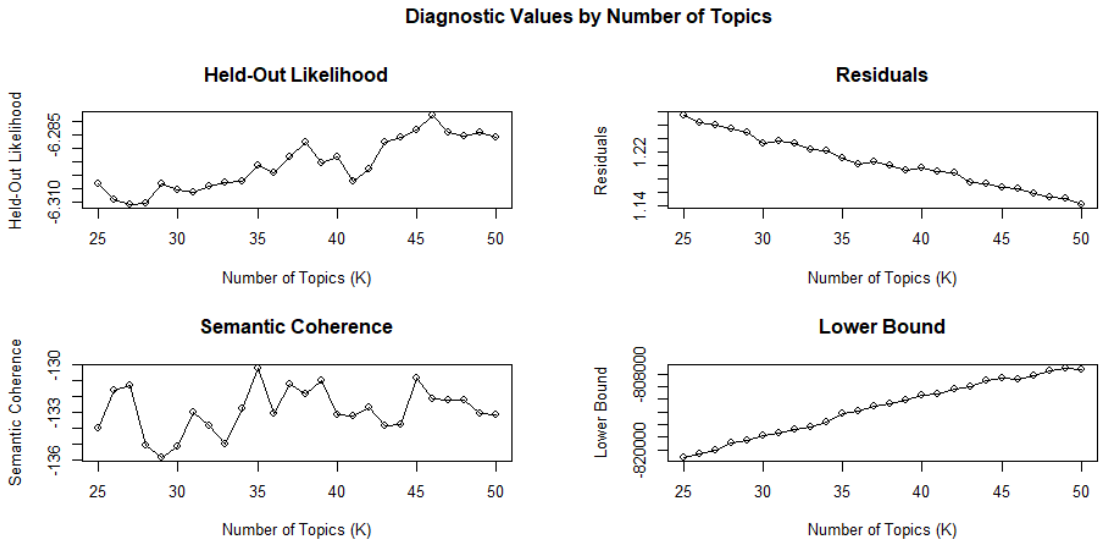
The 'stm' package includes the function *searchK()* that performs the estimation models with different *K* values to provide statistical analysis for the goodness of fit measures in topic modeling; it also provides a visualization of the results. Perplexity, semantic coherence, residuals, and lower bounds can be estimated and visualized, helping researchers select the optimal number of topics in a data-driven manner. However, statistical goodness of fit is not enough, and it is widely advised to apply human validation and human judgment in deciding the number of topics to model.

Four critical measures of goodness of fit are typically evaluated when determining the optimal number of topics to apply to a text corpus: perplexity, coherence, lower bound, and residuals. These metrics provide a statistical means to assess how well a given model fits the data, and they are essential tools in topic modeling. Perplexity called the held-out likelihood, gauges how well a probability model can predict unseen data. The logic behind this measure is straightforward: a model that can accurately anticipate data not used in its training is deemed a good fit. In this context, a lower perplexity score is more desirable, implying higher accuracy in the model's predictive capacity. Semantic coherence is a measure that aims to capture the semantic quality of a topic model. The concept behind this measure is that the most probable words within a topic should co-occur frequently in the corpus. In other words, the words most representative of a given topic should often be found together in the text (Roberts et al., 2014). Maximizing semantic coherence ensures that the topics generated by the model are meaningful and interpretable.

The lower bound indicator measures convergence in the iterations of the model. Convergence in this context refers to the point at which further iterations of the model do not significantly change the results. When the lower bound indicator shows only minor changes from one iteration to the next, this suggests that the model has converged, and further iterations are unlikely to yield significantly different results. Residuals are a diagnostic measure used to evaluate the dispersion of data around the fitted model. This measure calculates the degree to which observed data deviate from the model's predictions. If the residuals are greater than one (>1), this

suggests that the model may not be complex enough to capture the structure of the data, indicating that the number of topics set for the model may be too low (Taddy, 2011).

Figure 5. Estimation of Goodness of Fit Training Set (k) between 25 and 50



Source: Image created with 'stm' package

Figure 5 shows the visualization of the function searchK() results from the 'stm' package in the training set of the corpus; four goodness of fit measures are calculated for different values for K in a range from 25 to 50 topics. The held-out likelihood or perplexity values seem optimal in this range at k=46. Still, semantic coherence is higher between k=29 and k=30, and residual values above 1 indicate sample dispersion, meaning that the number for k is set too low. The lower bound value indicates model convergence; small changes between the compared values are preferred.

With this quantitative analysis of the four indicators of goodness of fit for topic models, we deemed 30 as the optimal number of topics to evaluate with the test set. First, semantic coherence is a crucial aspect of topic modeling. It measures the degree of semantic similarity between high-scoring words within topics. Higher semantic coherence indicates that the topics generated by the model are more interpretable for the researcher. Semantic coherence is highest at k=29; when the number of topics is in this range, the topics produced by the model are more meaningful and easier to interpret.

While the held-out likelihood or perplexity seems optimal at k=46, one should note that a balance between semantic coherence and perplexity is often sought in topic modeling. Although a higher perplexity score suggests that the model is better at generalizing to unseen data, it doesn't necessarily mean that the topics generated are interpretable or meaningful, which is an essential aspect of topic modeling. Therefore, trading off some perplexity for higher semantic coherence could be considered a reasonable compromise, achieved at k=29.

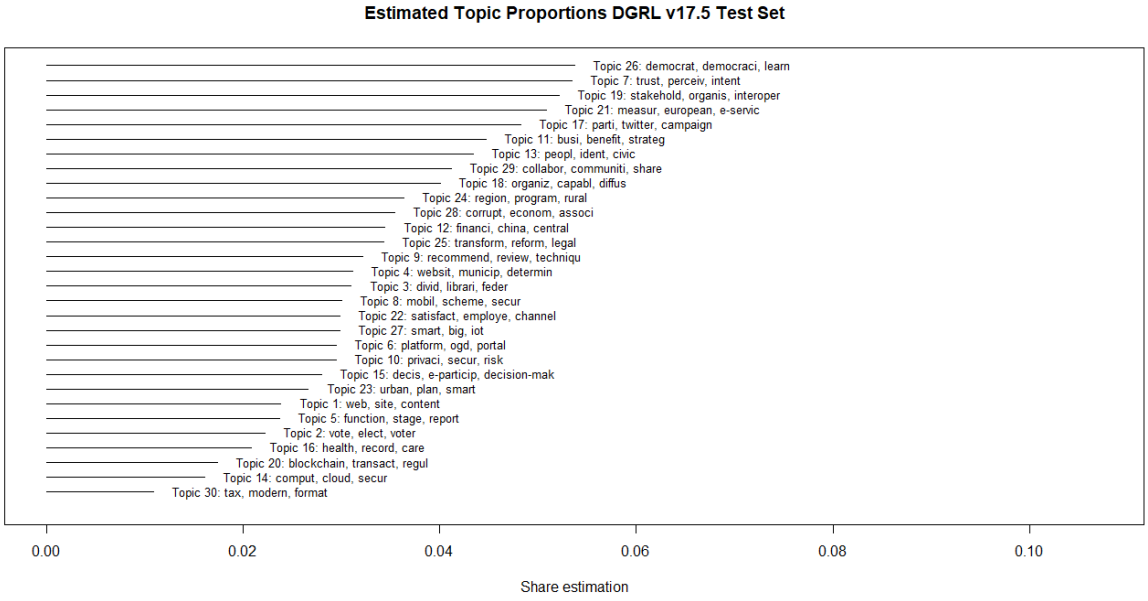
Finally, the residuals, which measure the sample dispersion, show that a value of k=29 is not set too high. Residual values above 1 indicate that the chosen number of topics is too low, suggesting that the model might be oversimplified. Therefore, choosing k=30 instead of k=29 provides a model with a slightly better value for the residual indicator, which might help capture more nuanced themes in the data without causing excessive complexity.

Like any other machine learning model, overfitting in topic models refers to a situation where a model is trained too well on the training data to the point where it starts to capture the noise or specificities in the training data instead of the underlying patterns. In the context of a topic model like Latent Dirichlet Allocation (LDA), overfitting might mean that the model fits so closely to the specific word distributions in the training documents that it becomes poor at generalizing to unseen documents. Choosing the correct number of topics to prevent overfitting is an art and can significantly impact the model's performance. Too many topics and the model might overfit; too few and it might underfit. Cross-validation techniques can be used to determine an optimal number of topics. Also, using a held-out validation set, as in this case, is deemed a best practice for this model and can help ensure that the model generalizes well to unseen data. To contrast the estimation of topic proportions for the training set (k=29), please refer to the GitHub repository; a plot of this estimation is provided in the graphics folder.

The ‘stm’ package includes the function labelTopics(), which allows the visualization of the most frequent words by topic and uses different adjustments to capture nuances in the topic-word probability distribution, thus aiming for the interpretation and human validation of the model. As mentioned above, we deemed k=30 the optimal number for the analysis. The resulting topic contents were derived from applying our model to the test dataset. For each topic, the table also displays the corresponding words with the highest probability of occurrence. This set of high-probability words gives a quick and intuitive sense of the underlying theme of each topic. Notably,

the topics and the highest probability words were generated through an unsupervised data-driven process, which aimed at delivering an accurate and detailed insight into the focal points of the data under scrutiny.

Figure 6. Estimated Topic Proportions Test Set



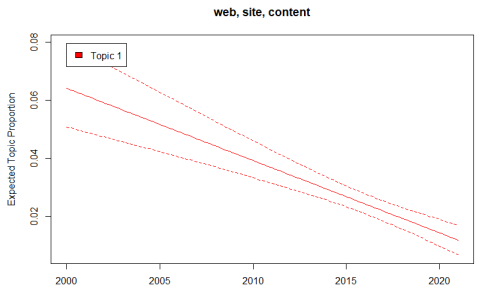
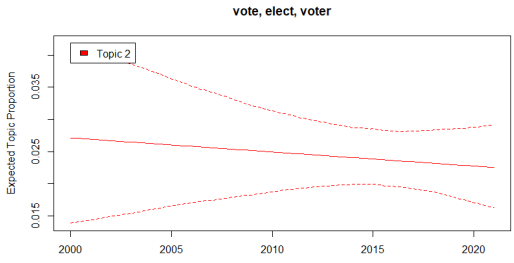
Source: Image created using the plot function of the ‘stm’ package

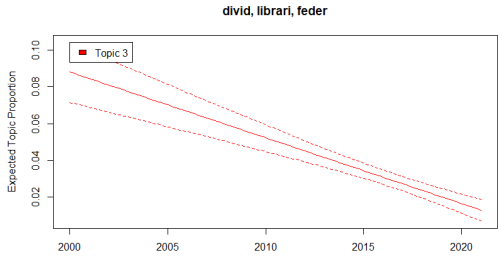
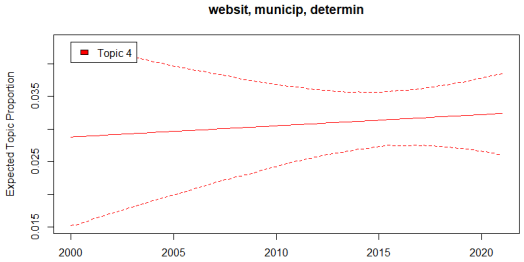
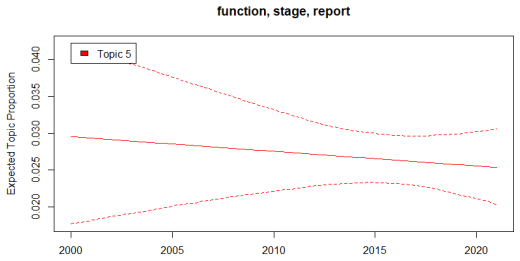
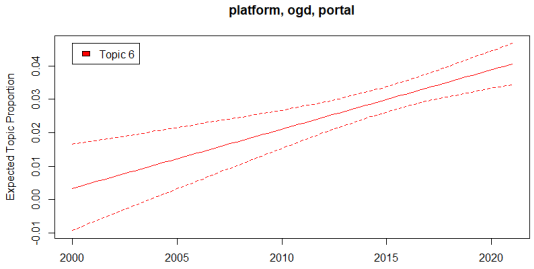
In addition, in the context of topic modeling, "FREX," "lift," and "score" are methods used to identify and interpret the most representative words for each topic. These metrics help researchers make sense of the topics generated by the model. *FREX* is the portmanteau word for FREquency and EXclusivity; FREX is a metric that balances the frequency of a word's appearance within a topic and its exclusivity to that topic. A word that appears frequently in a single topic but rarely in others would have a high FREX score, making it an excellent representative word for that topic. This is because it occurs often in the topic (frequency) and is distinctive (exclusivity). FREX can often provide more interpretability than just looking at word frequency alone. Lift is a measure of how much more often a word appears in a topic compared to its frequency in the entire corpus. A word with a high lift score in a topic means that it is particularly distinctive or unique to that topic, even if it might not be one of the most frequently occurring words. Lift can be beneficial for identifying keywords that are truly specific to a topic, helping to differentiate it from other topics. In this context, the term "score" is typically used to refer to a combined measure that considers

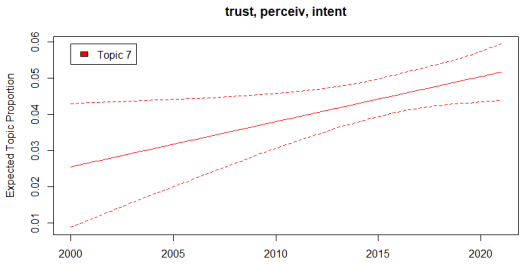
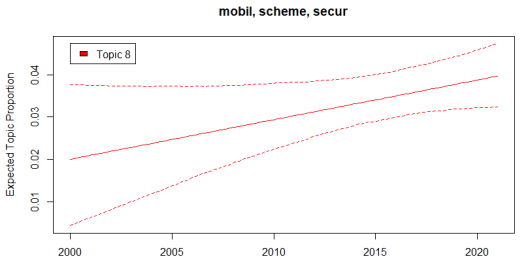
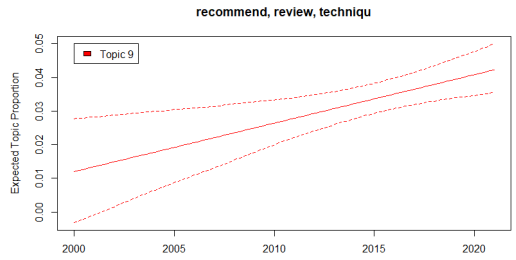
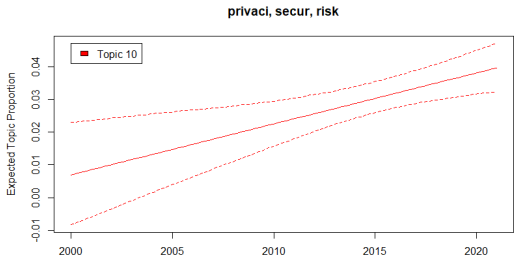
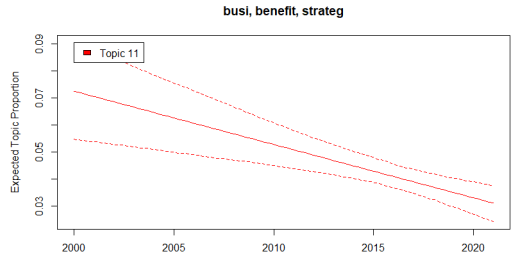
several factors to identify representative words for a topic. The specific elements included in the score can vary depending on the method or algorithm used. For example, in the 'stm' package in R, "score" is calculated as a weighted combination of a word's frequency in a topic, its exclusivity to that topic, and its overall frequency in the corpus. The weights can be adjusted to prioritize different aspects depending on the needs of the analysis. In summary, FREX, lift, and score are tools that can help interpret the output of a topic model. They each provide different perspectives on what makes a word representative of a topic. They can be combined to gain a more nuanced understanding of the topics generated by the model.

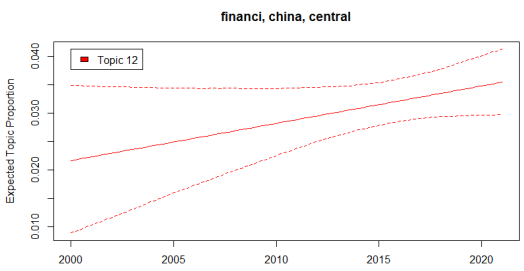
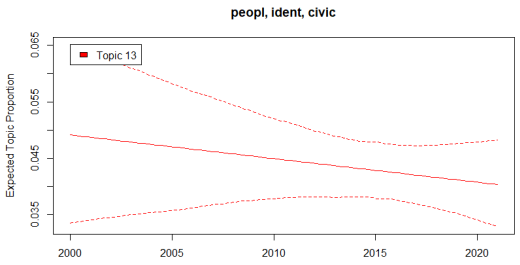
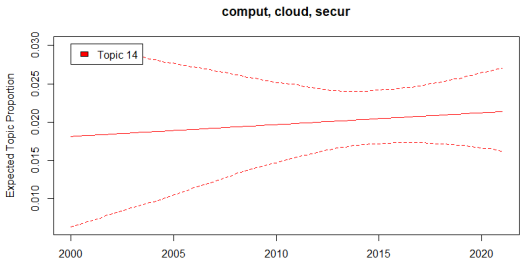
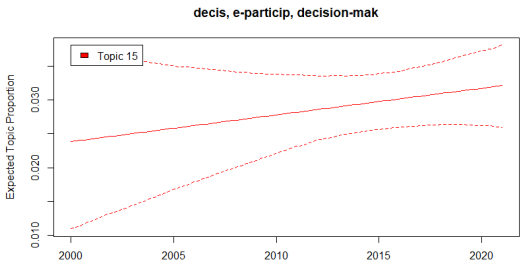
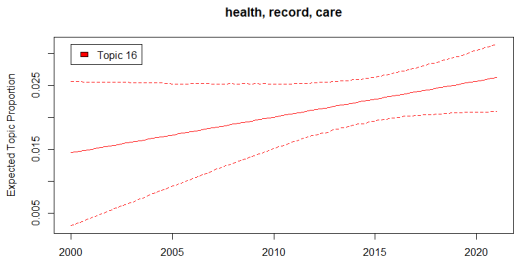
Table 3 contains the list of 30 topics, the ten most frequent and exclusive words for each topic, a human interpretation of the cluster of words, and the estimation of topic prevalence over time by using the labelTopics() function of the 'stm' R package, and by giving more weight to the interpretation of topics to the Frequency and Exclusivity of words to each topic, and a visualization of the prevalence of each topic over time. For a more complete output of the labelTopics() function, please refer to Appendix 1.

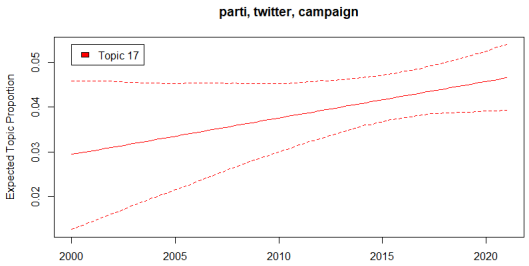
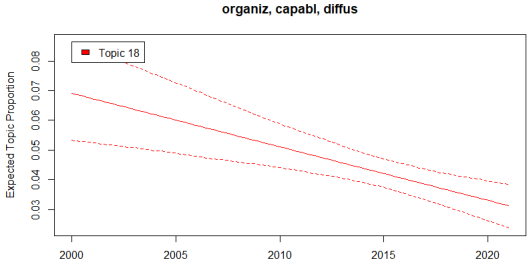
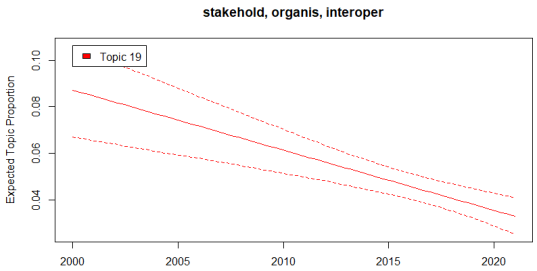
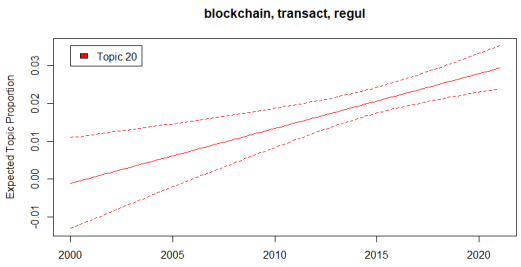
Table 3. Frequency and Exclusivity of Words by Topic and Topic Prevalence over Time

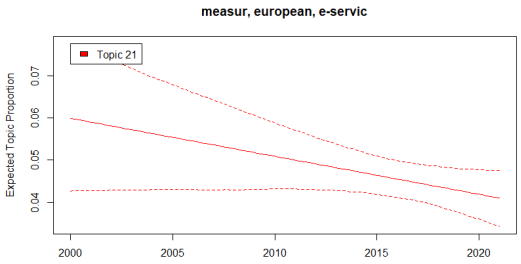
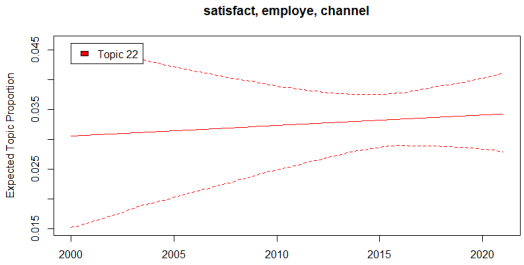
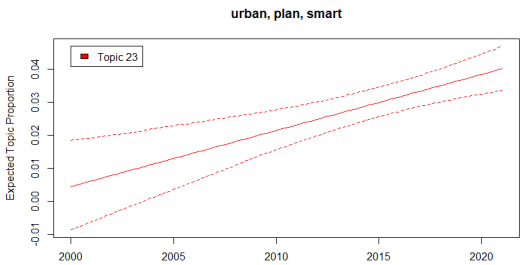
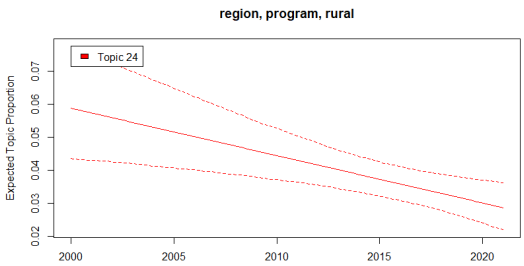
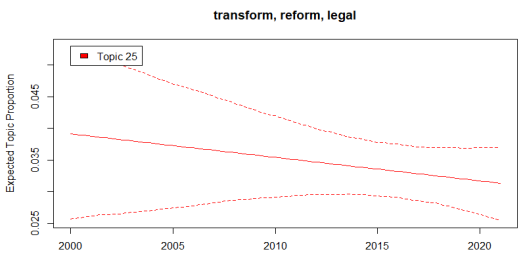
TOPIC	FREX	Interpretation of Topic	Topic Prevalence over Time
Topic 1	web, site, de, search, usabl, ontolog, content, web-bas, section, presenc	(Web technologies) Use of web technologies in Digital Government	
Topic 2	vote, e-vot, voter, ballot, elect, elector, imag, protocol, verifi, procedur	(Electronic Voting)	

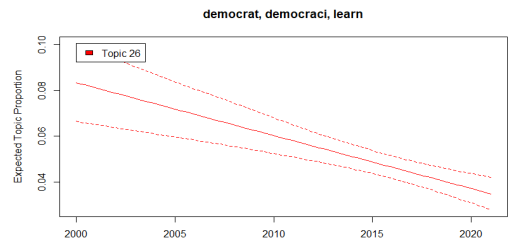
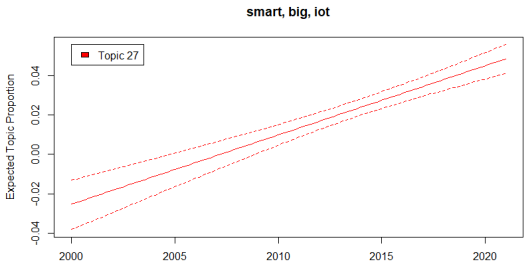
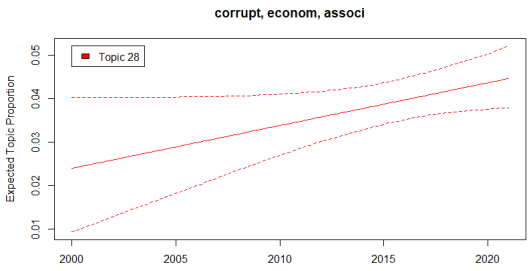
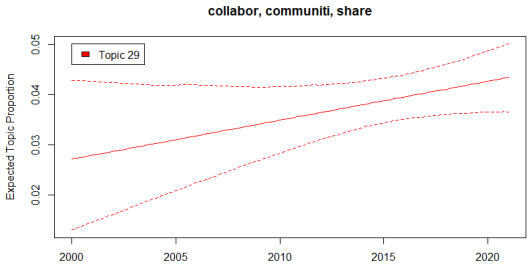
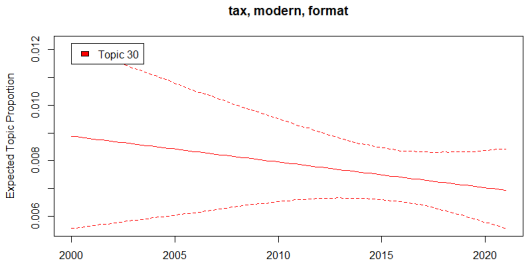
TOPIC	FREX	Interpretation of Topic	Topic Prevalence over Time
Topic 3	librari, divid, feder, email, scienc, copi, educ, uk, africa, materi	(Boilerplate Topic) When topics do not have a consistent word pattern these are considered "boilerplate topics".	
Topic 4	municip, websit, disclosur, degre, spanish, index, variabl, determin, budget, sampl	(Local government website, possible boilerplate topic)	
Topic 5	polic, offic, conflict, stage, function, app, crime, report, contact, depart	(Policing and crime)	
Topic 6	ogd, platform, portal, barrier, dataset, principl, element, account, releas, lack	(Open Government Data)	

TOPIC	FREX	Interpretation of Topic	Topic Prevalence over Time
Topic 7	intent, perceiv, trust, attitud, accept, behavior, eas, usag, equat, m-govern	(Trust and adoption models)	
Topic 8	scheme, authent, detect, identif, mobil, signatur, devic, reliabl, entiti, attack	(ID Management)	
Topic 9	recommend, intellig, ai, analyt, algorithm, techniqu, machin, artifici, review, extract	(Artificial intelligence and recommendation systems)	
Topic 10	privaci, cyber, protect, threat, risk, cybersecur, secur, person, vulner, concern	(Cybersecurity and Privacy)	
Topic 11	custom, strateg, busi, procur, benefit, realiz, e-procur, cost, suppli, failur	(e-Procurement)	

TOPIC	FREX	Interpretation of Topic	Topic Prevalence over Time
Topic 12	china, financi, central, chines, global, economi, intern, bank, leadership, account	(China, boilerplate topic)	
Topic 13	citizenship, ident, offlin, peopl, student, civic, young, age, movement, regim	(Civic duties)	
Topic 14	cloud, comput, taiwan, secur, firm, flexibl, univers, australian, australia, softwar	(Cloud computing)	
Topic 15	e-particip, decision-mak, decis, participatori, policy-mak, environment, foster, map, prefer, cognit	(e-participation, decision making)	
Topic 16	health, care, patient, record, medic, preserv, readi, archiv, databas, background	(Health)	

TOPIC	FREX	Interpretation of Topic	Topic Prevalence over Time
Topic 17	campaign, candid, twitter, facebook, news, parti, post, comment, tweet, messag	(Social media)	
Topic 18	diffus, capabl, organiz, matur, characterist, task, contextu, e-gov, guid, theoret	(Maturity models in E-Government)	
Topic 19	stakehold, interoper, organis, egovern, standard, privat, conceptu, concept, complex, technic	(Interoperability)	
Topic 20	blockchain, transact, contract, asset, decentr, regul, distribut, exchang, ensur, trust	(Blockchain)	

TOPIC	FREX	Interpretation of Topic	Topic Prevalence over Time
Topic 21	e-servic, european, benchmark, eu, measur, evolut, union, journal, index, year	(e-Services in the European Union)	
Topic 22	employe, satisfact, job, channel, resist, motiv, questionnair, government, skill, train	(Human Resources)	
Topic 23	urban, plan, compon, energi, grid, land, infrastructur, product, spatial, architectur	(Smart cities)	
Topic 24	region, rural, broadband, program, deliveri, e-commerc, rate, fund, popul, invest	(Broadband penetration, rural)	
Topic 25	reform, transform, legal, court, rule, legisl, law, justic, definit, servant	(Regulatory issues, law)	

TOPIC	FREX	Interpretation of Topic	Topic Prevalence over Time
Topic 26	democrat, e-democraci, democraci, debat, deliber, crowdsourc, learn, space, civic, forum	(Democratic values and practices)	
Topic 27	iot, big, smart, transport, thing, sustain, traffic, life, industri, safeti	(Internet of Things)	
Topic 28	corrupt, greater, moder, negat, estim, percept, associ, econom, reduc, societi	(Corruption, boilerplate topic)	
Topic 29	disast, covid-19, collabor, crisi, communiti, event, action, share, pandem, monitor	(Covid-19, pandemic issues)	
Topic 30	tax, format, modern, us, crucial, featur, phase, character, necessari, economi	(Tax issues)	

Source: Topic labels and topic prevalence over time created with the 'stm' package.

In the set of thirty topics explored within the held-out data, a noteworthy quartet, closely associated with automation technologies, is identifiable by interpreting the most frequent and exclusive string of words. These four topics are topic 9, “artificial intelligence,” topic 14, “cloud infrastructure,” topic 20, “blockchain,” and topic 27, “Internet of Things.” Each of them shows a growing trend in topic prevalence over time; this can be interpreted as a sustained research interest in the field of Digital Government.

In addition, Topic 22, labeled "Human Resources," – featured strings of words associated with work or employment. The words with the highest probabilities within this topic included terms like 'employee,' 'job,' 'skill,' and 'train,' suggesting a cluster of documents that consistently use these words in a related context, forming a distinct topic. These terms collectively point towards workforce development, employee management, job-related skills, and vocational training, elements central to discussions around 'Human Resources.' This topic likely captures discussions around the role of human resources in Digital Government, the development of digital skills within the workforce, and possibly the impact of technological advancements on employment and job training.

Figure 7. Word cloud for Topic 22, “Human Resources.”

Source: Visualization made with ‘stm’ package

Figure 7 provides a more detailed visual representation of this topic through a word cloud, which displays the most salient terms associated with Topic 22. The size of each term within the

word cloud corresponds to its frequency within the topic, allowing for a quick and intuitive grasp of the most dominant themes within the 'Human Resources' topic. This word cloud serves as a valuable aid in visually interpreting the core components of this topic, reinforcing our understanding derived from the FREX analysis.

Despite the robustness of the 'stm' package, it has limitations, particularly regarding the visualization of the models. These shortcomings may restrict how researchers present and interpret their findings, potentially limiting the insights gained from the data. Fortunately, advancements in associated software packages have been made to enhance interpretability and address these limitations. One of them is LDAvis (Sievert & Shirley, 2014); this visualization tool provides interactive web-based visualization of topics produced by Latent Dirichlet Allocation (LDA) and other topic models, allowing users to explore the relationships between topics and the words that constitute them. This level of interactivity can significantly enhance the interpretability of topic models, making it easier for researchers to understand and communicate the results of their analysis. The Intertopic Distance Map is a crucial feature of the LDAvis package in R, which is used to create interactive visualizations of topic models generated by Latent Dirichlet Allocation (LDA). The Intertopic Distance Map is a two-dimensional scatterplot where each point represents a topic. The distance between points reflects the similarity between topics. More specifically, closer points represent topics with many common terms, indicating that these topics are similar. Conversely, points further apart mean topics with few common terms, suggesting that these topics are distinct or dissimilar.

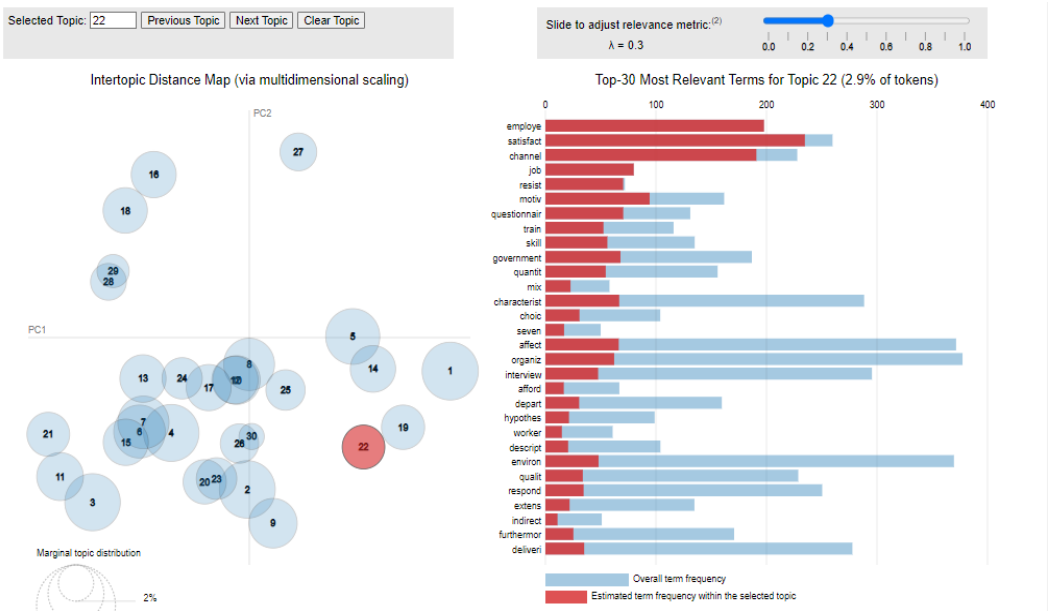
The positions of the topics (points) in the plot are determined using multidimensional scaling (MDS). MDS is a way of reducing the dimensionality of data – in this case, the high-dimensional space of topics and terms – into a lower-dimensional space that can be easily visualized (in this case, two dimensions). The size of each point (topic) in the Intertopic Distance Map is proportional to the proportion of the total corpus of that topic. Therefore, more prominent points represent more prevalent topics in the corpus. When you select a topic in the Intertopic Distance Map, LDAvis displays a bar chart on the right side of the screen showing the most relevant terms for the topic chosen. The measure of "relevance," also known in topic modeling as lambda (**λ),** can be adjusted using a slider, allowing you to see how the most relevant terms change as you adjust the weight given to the term frequency within the selected topic relative to its frequency across all topics.

Figure 8 displays Topic 22, labeled “Human Resources,” using the LDAvis package. LDAvis is a powerful tool for exploring and interpreting topic models, allowing for an in-depth exploration of the specific string of words or 'tokens' most closely associated with a particular topic. One of the distinguishing features of LDAvis is its interactive '*lambda*' parameter, which can be adjusted within the visualization. In the context of topic modeling, lambda represents the ratio of the frequency of a token within a specific topic to its overall frequency across all topics.

By adjusting the lambda value, we can alter the balance between the term frequency within the topic and its exclusivity to the topic. High lambda values highlight the most frequent terms in the topic. Lower lambda values emphasize terms that are more exclusive or unique to the topic. This allows us to identify the most used words within the topic and those most characteristic or distinctive, providing a more nuanced understanding of the topic's thematic structure.

Figure 8 provides a visual representation of the relationships between various research topics in the form of an Inter-topic Distance Map. Notably, it depicts Topic 22 as relatively isolated from the other cluster of topics. This isolated positioning is significant as it implies that while human resources issues are indeed a subject of investigation within the corpus, they are not intimately tied to topics related to other topics or, with automation technologies topics, our topics of interest.

Figure 8. Visualization of Topic 22, “Human Resources,” using LDAvis



Source: Visualization using LDAvis, lambda parameter adjusted at 0.3

Visualization of topic models is probably one of the most powerful tools developed in recent years to help researchers interpret the results of a topic model. It may explain the increasing adoption of these techniques in different fields than computer science. Visualizing the rest of the topics from this exercise in this format defeats the chapter's purpose. However, for an interactive view of the topics, the code and tools for visualization are documented in the GitHub repository in the script treating the test set.

5. Discussion and conclusions

Despite the broad adoption of topic modeling across numerous fields, we believe this study represents the inaugural application of this methodological approach to a corpus centered on Digital Government. This novel exploration enables a comprehensive understanding of the existing literature and facilitates the identification of emergent trends and the evolution of research interest over time. We had interpretable results from an “unseen dataset” during our analysis after refining the different model parameters with the training set. For replicability purposes, all the data, graphics, and script are open for revision from the GitHub repository.

During the processing of the dataset, one of the first analyses after deciding if to use a stemming algorithm was to create a word cloud of the most prevalent in the DGRL corpus, as seen in Figure 2 of this document. The contents of this word cloud might be apparent. Strings of words that are readily identifiable given the corpus selected. Government, e-government, technology, data, and the public are some of the words that are more salient in the collection of documents.

Perhaps a more illuminating visualization is depicted in Figure 3, which presents the most salient bigrams or pairs of words that frequently occur together within our corpus. This visualization provides a nuanced understanding of the relationships between different themes and how they coexist within the realm of Digital Government. Bigrams such as 'social media,' 'smart cities,' 'open data,' and 'open government' emerge as particularly prevalent, signifying their significant role in shaping the discourse in this field.

The prevalence of 'social media' as a bigram is particularly noteworthy. Its prominence extends beyond its mere frequency in the corpus; it represents a crucial node within the network of topics, highlighting its central role in the Digital Government discussion. Moreover, 'social

media' was easily identified by the human interpretation of each topic's themes (FREX words). Topic 17 was labeled “Social media” due to an easily identifiable collection of words, becoming a distinct topic within the topics discovered by our model, further underscoring its centrality. In addition, the estimation of topic prevalence over time is positive, which can be interpreted as a growing field of research interest and likely a promising area of research.

Several other bigrams, or pairs of words, also play a significant role in interpreting the corpus, including phrases like "case study," "big data," and "literature review." These bigrams serve as essential signposts that highlight the key themes of interest and shed light on the preferred research methodologies and analytical techniques employed within the Digital Government field. The term "case study" suggests a prevalent use of qualitative research methods, where specific instances or 'cases' are studied to gain a nuanced understanding of a phenomenon. This approach allows researchers to delve into the complexities and context-specific aspects of Digital Government, providing rich, detailed insights.

"Big data," on the other hand, indicates an interest in using large, complex datasets for analysis. This could involve data analytics, data mining, and predictive modeling, reflecting the growing trend of leveraging massive data sets to derive insights in the realm of Digital Government. Finally, "literature review" suggests a substantial focus on synthesizing existing knowledge. Literature reviews map out the current research landscape, identify gaps, and set the stage for future investigations. They are crucial for maintaining a continuous dialogue with past studies and ensuring that new research builds upon existing knowledge. In essence, these bigrams offer a valuable snapshot of the field's current preoccupations regarding subject matter and research methodology. They provide a roadmap for understanding the complex tapestry of the Digital Government field, highlighting areas of ongoing interest and the diverse tools researchers employ to probe them.

Figure 4 shows the most prevalent trigrams within the corpus, groups of three words frequently appearing together. This approach allows for a deeper exploration of more complex themes within the corpus than bigrams, which only consider pairs of words. One trigram that stands out in this visualization is "open government data." This phrase, appearing frequently within the corpus, points to a significant theme within the field of Digital Government. Its recurrence suggests that making government data freely available to the public is a central topic of discussion within

the literature. Further corroborating this observation, "Open Government Data" has been identified as the label for Topic 6 within our topic model. Examining the trends in topic prevalence over time reveals a growing interest in this area. This suggests that "Open Government Data" is not only a current focal point but also likely to be an increasingly important theme in the future discourse surrounding Digital Government. This identification and tracking of key themes over time illustrate the strength of topic modeling as a tool for understanding and predicting trends within a field of study.

Beyond the prominent theme of "open government data," Figure 4 reveals several other intriguing trigrams that provide additional insights into the corpus. Phrases such as “structural equation modeling,” “technology acceptance model,” “new public management,” “critical success factors,” and “partial least squares” emerge as particularly notable. These trigrams represent some of Digital Government literature's most salient methodologies and conceptual frameworks. For instance, "structural equation modeling" and "partial least squares" suggest advanced statistical methods to investigate complex relationships between variables of interest. Similarly, the “technology acceptance model” points towards a frequently used framework for understanding how users accept and use technology. The phrase “new public management” reflects discussions around the modernization of public sector services, often through adopting practices from the private sector. Lastly, “critical success factors” focus on identifying the key elements necessary to implement digital government initiatives successfully.

These trigrams, therefore, not only hint at the content of the literature but also provide a glimpse into the theoretical and methodological foundations that underpin the field. As such, they offer a valuable perspective for understanding the current state of the discourse and could guide future research directions in Digital Government studies.

5.1. Dominant topics in the Digital Government literature

Figure 6 presents the estimated topic proportions in the test set of the corpus. Addressing Research Question 1, the top 5 topics are as follows: Topic 26, Topic 7, Topic 19, Topic 21, and Topic 17. Topic 26, labeled “Democratic values and practices,” is one of the most predominant topics in the corpus, with a decreasing topic prevalence over time, as seen in Table 3. This

observation may hint at the changing and evolving research interests of the Digital Government field. Still, it could inform on the diversification of research topics within this area of research.

The next most predominant topic in the corpus is Topic 7, labeled “Trust and adoption models,” a topic that is also identifiable by the researcher’s experience and accumulated and tacit knowledge of the corpus as a dominant research theme in the literature. Topic 7 presents a positive topic prevalence over the years, indicating *a leading conceptual apparatus* and growing sub-field of research.

Topic 19 has been labeled as “Interoperability” given the interpretation of FREX string of words such as ‘stakehold,’ ‘interoper,’ and ‘standard.’ The topic prevalence of this subfield showed a relatively high interest by the early 2000s and a decline in prevalence over time. Keep in mind that research output has increased dramatically mainly since 2010, as seen in Figure 1, something to consider given that, as mentioned above, in the Digital Government literature, there might be an evolution, diversification of research topics, and an apparent increase in research output within the field.

Topic 21 is also one of the leading topics by proportion in the corpus. The label assigned for this topic is “e-Services in the European Union.” The FREX string of words like ‘benchmark,’ ‘measure,’ and ‘e-servic’ hint at the abundant research initiatives carried out in the European Union about e-services. Several attempts to measure public sector innovation and the production and delivery of e-services have been on the research agenda of Digital Government scholars. The prevalence over the years of Topic 21 is declining. As mentioned above, social media has been identified as a central topic in the Digital Government corpus under revision. In particular, Topic 17, labeled as “Social media,” contains a FREX string of words like ‘campaign,’ ‘candid,’ ‘twitter,’ ‘facebook’, and ‘parti’ that may hint at using social media for the electoral campaign. The prevalence of topic 17 in the corpus shows a growing trend.

5.2. Automation technologies topics and Topic 22 “Human Resources”

Recognizing several key topics underscores the interrelationship between digitalization and other automation technologies within the analyzed corpus. Specifically, these include Topic 9, which is categorized as "Artificial Intelligence," Topic 14, dubbed "Cloud," Topic 20, referred to

as "Blockchain," and Topic 27, titled "Internet of Things." Each of these topics serves as a cornerstone in the landscape of modern automation technologies. They are not merely standalone concepts but are intrinsically linked, forming a cohesive fabric of digital transformation.

As seen in Table 3, these topics exhibit a consistent and rising trend in their prevalence as per the estimation of the year covariate. This trend indicates an ascending trajectory of scholarly interest in literature that addresses the issues intertwined with automation technologies. It's an important observation that suggests the increasing prominence of these themes in academic discourse.

From the array of thirty distinct topics that emerged from our analysis, a single topic – Topic 22, labeled "Human Resources" – stood out for its association with work and employment. The terms most strongly associated with this topic – 'employee,' 'job,' 'skill,' and 'train' – recur significantly, suggesting a cohesive group of documents where these terms frequently co-occur, thereby carving out a unique thematic space within the corpus. The confluence of these terms hints towards a central theme of workforce development and management. 'Employee' and 'job' likely reflect discussions around employment dynamics, human resources management, and the evolving nature of work within the context of Digital Government. The prominence of 'skill' and 'train' emphasizes education, skill development, and vocational training, highlighting the importance of equipping the workforce with the necessary skills to navigate the digital landscape. Topic 22 appears to encapsulate a rich tapestry of discussions centered on 'Human Resources.' It likely delves into the role of human resources in the realm of Digital Government, the importance of nurturing digital skills within the workforce, and the potential ramifications of rapid technological evolution on employment patterns and job training requirements.

As seen in Figure 8, in the intertopic distance, Topic 22, focusing on the complexities and nuances of human resources, seems to operate within a separate sphere of inquiry compared to the constellation of topics revolving around automation technologies in the public sector. This finding suggests that, despite the ongoing revolution in automation technologies, the study of human resources retains its unique ground. It also indicates that the intersections between human resources and automation may not be as thoroughly explored or defined as one might assume. This relative isolation could be due to a variety of reasons. Perhaps the human-centered nature of human

resources issues necessitates a different analytical lens, or there may be a gap in the literature that has yet to explore the interplay between human resources and automation technologies fully.

The isolated nature of Topic 22, human capital, could indicate a prevailing assumption or bias within academia that automation technologies and human capital exist in separate domains. This could be an artifact of a conventional dichotomy where technology and human resources are viewed as separate entities. In addition, this finding might reflect disciplinary silos within academia. Discussions about automation technologies often occur within technical fields like computer science or engineering. At the same time, human capital tends to be a topic of interest in social sciences or business studies. This could potentially point to a need for more interdisciplinary dialogue and research.

The separation might also signify a time lag in academic response. As automation technologies continue to evolve, research in human capital might not yet have had enough time to catch up and fully integrate these technological advancements into its discourse. It is important to remember that this analysis should be further validated by additional research to confirm or disconfirm these interpretations. Future work might also explore ways to bridge the gap between these fields and encourage a more holistic view of the relationship between human capital and automation technologies. Regardless, the evidence from Figure 8 suggests that the academic discourse around these topics maintains distinct streams of conversation, presenting an intriguing area for further investigation.

Thus, addressing Research Question 2, exploring this topic can provide valuable insights into how Digital Government initiatives intersect with human resource management and workforce development strategies, shedding light on the human element that underpins the digital transformation journey. As for the topic prevalence over time, the trend is positive but almost negligible. The exploration via topic modeling of a Digital Government corpus sustains the initial argument that labor-related issues are developing and may present further research opportunities.

5.3. Topic relative prevalence growth and decline over the years

Leveraging the power of the 'stm' package in topic modeling, we utilized the temporal dimension, specifically the year, as a covariate in our analysis. This approach allows us to estimate

how the prevalence of various topics has evolved, providing insights into shifting trends and emerging areas of interest within the Digital Government field and addressing Research Question 3. During our examination of the test set of our corpus, we identified several topics that exhibit a growing trend in their prevalence over time. These include:

Topic 4: "Local Government"; Topic 6: "Open Government Data"; Topic 8: "ID Management"; Topic 9: "Artificial Intelligence"; Topic 10: "Cybersecurity and Privacy"; Topic 14: "Cloud Computing"; Topic 15: "e-Participation"; Topic 16: "Health"; Topic 20: "Blockchain"; Topic 22: "Human Resources"; Topic 23: "Smart Cities"; Topic 27: "Internet of Things"; Topic 29: "Covid-19".

These topics span a wide array of themes, from technology-related topics like "Artificial Intelligence," "Blockchain," “Cybersecurity” or “The Internet of Things” to more overarching themes like "Local Government," "Health" and “Smart cities,” indicating the diverse range of subjects growing in prominence within the Digital Government discourse. Moreover, the unsupervised classification of topics like "Covid-19" showcases the responsiveness of the field to contemporary global events. These trending topics could potentially shape the direction of future research in Digital Government, underscoring the importance of temporal analysis in understanding the evolving landscape of the field.

Conversely, our analysis also pointed to specific topics that have experienced a decline in prevalence over time. These trends offer equally valuable insights, hinting at areas where interest may be waning or shifting to other emerging subjects within the field of Digital Government. The topics that exhibit this downward trend include Topic 1: "Web Technologies"; Topic 2: "Electronic Voting"; Topic 5: "Policing and Crime"; Topic 11: "e-Procurement"; Topic 13: "Civic Duties"; Topic 18: "Maturity Models"; Topic 24: "Broadband Penetration, Rural"; Topic 25: "Regulatory Issues"; Topic 30: "Tax Issues."

These topics cover a broad spectrum of issues, ranging from technological aspects like "Web Technologies" and "Broadband Penetration, Rural" to more process-oriented themes such as "Electronic Voting" and "e-procurement." The decrease in prevalence could suggest a shift in research focus, possibly due to the maturation of specific subjects, evolving research interests, or the emergence of new, more pressing issues. For instance, the decline in "Web Technologies" could be attributed to the field's maturation, with newer, more advanced technologies (i.e., Mobile

technologies) taking the spotlight. Similarly, less attention to "Broadband Penetration, Rural" might reflect advancements in infrastructure, reducing the urgency of this issue. The evolving prevalence of these topics underscores the dynamic nature of the Digital Government field. It highlights the importance of staying up-to-date with these shifts to align future research efforts with the most pertinent and contemporary issues.

5.4. Boilerplate topics

In the context of topic modeling, a "boilerplate" topic typically refers to a topic composed of ordinary, generic words or phrases that do not carry much specific or thematic meaning. These words often appear frequently across many or all documents in a corpus, but they do not contribute significantly to the content or themes of the papers. For example, in a corpus of legal documents, a boilerplate topic might include common legal phrases that appear in many legal documents but do not indicate the specific legal topic of the document. Similar outcomes are commonly seen in dimensionality reduction techniques such as factor analysis.

Our analysis also revealed a set of topics that did not exhibit clear interpretability based on the FREX (Frequency-Exclusivity) string of words associated with each topic. The words' relationship and connection to the underlying topic were not readily discernible in these cases. This lack of clear interpretability is often encountered in topic modeling, leading to what is commonly referred to in the literature as "boilerplate topics." Boilerplate topics are a product of the topic modeling algorithm's application, but they fail to yield transparent or interpretable results. They may be composed of words frequently appearing together in the corpus but do not form a coherent theme or concept. These topics can be considered 'noise' within the model and are typically not of substantive interest. In our study, we identified the following as boilerplate topics:

Topic 3: "Library" - The term 'Library' may be frequently used in the corpus, but its context or specific theme remains unclear. Topic 12: "China" - While 'China' is a frequent term, the lack of additional context or related terms leaves the topic's precise theme ambiguous. Topic 28: "Corruption Perception" - Although 'Corruption Perception' could point towards an intriguing theme, its exact significance remains elusive without further context or coherent related terms.

Identifying and acknowledging these boilerplate topics is crucial to the topic modeling process, ensuring that subsequent analyses and interpretations are focused on meaningful and interpretable topics. Another interpretation of boilerplate topics might be the need to increase the number of topics, a higher *k* to run the model. In our fine-tuning with the training set, we ran simulations with higher values of *k; this* may improve the classification of words into more topics to achieve a different level of granularity in the analysis.

Using topic modeling techniques for a "smart literature review" is deemed experimental to analyze this corpus of Digital Government Research. To the best of our knowledge, this exercise has not been implemented before in the field. Computer-assisted techniques for evidence synthesis are becoming more and more available outside of the computer science field. They are enabling researchers in other areas to use powerful and novel tools to explore the ever-growing research output in most fields of knowledge, thus enriching the methodological repertoire of said researchers. In addition, incorporating these new methodologies in research practice includes adopting "best practices" for data processing, analysis, and the communication of research in a programmatic and reproducible way.

Visualization of topic models is probably one of the most powerful tools developed in recent years to help researchers interpret the results of a topic model. It may explain the increasing adoption of these techniques in different fields than computer science. These new forms of visualization are an opportunity to call for an interactive way of presenting research results using reproducible and programmable approaches. We adhere to good research practice to document all the processes from data retrieval, data analysis, and presentation of results. For evaluation and reproducibility purposes, the data, script, and tools for visualization are documented in this project's GitHub repository.

In the analyses via n-gram visualization, it was particularly unanticipated to see the massive footprint of social media in Digital Government scholarship; the ample reach of this issue includes government-citizens interactions, the delivery of public services, and the influence in political campaigning. Another "unanticipated" aspect was the prevalence of quantitative approaches, as discussed above with the word prevalence of bigrams and trigrams. Digital Government scholarship has generally been associated with qualitative methods; finding a balance between qualitative and quantitative approaches is refreshing.

Using an ‘enhanced’ topic modeling technique (STM) that incorporates covariates found in the metadata of documents for topic prevalence estimation is a significant evolution in the field. It provides researchers with the analytical tools to estimate the probabilities of topic prevalence given the covariates of interest (in our case, a time variable). Computational social science is not an isolated ‘research trend’; the exponential growth in research output and the increased availability of diverse types of data due to the digitalization of everyday life is pushing early-stage researchers to learn how to work with (more extensive) data and feel comfortable about it.

The topic prevalence estimation demonstrated increased probabilities over time for topics related to the “iABCD” technologies (internet of things, artificial intelligence, blockchain, cloud, and data analytics); these technologies have been conceptually associated with transformations in the organization of work. Thus, exploring the nexus between digital technologies and the public sector workforce seems promising, like a field of further inquiry in a public sector context. However, via the intertopic distance map, we could visualize no overlap in the study of automation technologies and issues related to human resources or human capital development. Thus suggesting a gap in the literature in the exploration of automation technologies and the organization of work in the public sector.

Significant developments have updated our initial assumptions; the health crisis of 2020 fostered the adoption of digital technologies and the reorganization of work processes in the whole economy. Culturally, it pushed citizens and firms to be more comfortable with a technology-mediated interaction, a different public encounter. A digital public encounter changes the organization of work and the provision of services by government organizations. The public sector is a significant employer, a primary adopter of ICT technologies (not to mention AI applications), and a key player in the big data value chain.

Using topic modeling is a promising method to explore and analyze bibliographic content in a reproducible, scalable, and programmable manner. However, it is essential to consider the limitations of text-as-data methods. As mentioned in the literature review section of this document, the selection and treatment of a corpus have “consequential” effects on the result of the analysis, and there might be some caveats and limitations that need to be acknowledged in implementing this method.

Resource Bias refers to the bias that can occur when the availability or accessibility of resources influences the selection of a corpus. For instance, researchers might analyze readily available texts or require fewer computational resources to process, which might not represent the broader population of texts. Incentive Bias arises when the selection of texts is influenced by the incentives of the researchers or the entities providing the texts. For example, a researcher might choose to analyze texts that are more likely to support their hypothesis, or a company might provide access to texts that present it in a positive light.

Medium bias occurs when the selection of texts is influenced by the medium in which they are published. For example, researchers might analyze texts published in digital format because they are easier to process, which might exclude important texts published in other mediums. Retrieval bias refers to the possibility that some relevant texts might not be retrieved due to limitations in the search or retrieval process. For example, a search algorithm might not retrieve all relevant texts due to restrictions in its design or implementation.

In addition, from a theoretical perspective, developing native theoretical frameworks within Digital Government Research could enhance the coherence and robustness of the field, fostering a deeper understanding of the specific issues and challenges that arise in the context of digital government. Additionally, by establishing its theoretical underpinnings, DGR may be better positioned to integrate and synthesize knowledge from diverse contributing disciplines, facilitating the creation of more comprehensive and holistic insights into the rapidly evolving landscape of digital government.

Despite the significant advantages of using unsupervised machine learning approaches to explore a bibliographic corpus, alternative approaches suggest using concept-centric methods in conjunction with topic modeling, which can be achieved using "seed word dictionaries" in semi-supervised topic models. However, this technique's application falls beyond this chapter's scope and could be considered a possible evolution for upcoming research products. Also, an alternative exploration of the corpus may be conducted by tweaking the number of topics to achieve a different level of granularity in the analysis by exploring another optimal and interpretable number of topics.

By exploring the Digital Government Research Library version 17.5 using an unsupervised topic modeling approach, we would like to argue that there is a significant gap in the extant literature as regards the relationship between automation technologies and the public sector

workforce. Despite the profound implications of these technologies, there seems to be a significant gap in the existing literature concerning their impact on the organization of work in the public sector. The Digital Government Research Library has been explored in-depth to find any significant linkages in the literature connecting these two issues with no considerable success.

The exploration of the linkages between automation technologies and the organization of work in the public sector is paramount for several reasons. Firstly, automation technologies have the potential to significantly alter the nature of work, job roles, and employment structures within the public sector. Understanding these changes can help policymakers and public sector leaders better manage the transition towards more automated processes, ensuring that automation's benefits are exploited while curtailing any potential negative impacts on the workforce. Secondly, many jurisdictions consider the public sector one of the largest employers. Therefore, insights gained from studying the effect of automation technologies on the public sector workforce could have broader implications for the wider labor market.

Furthermore, the public sector plays a crucial role in society, providing essential services and upholding the functioning of the state. Any changes to work organization within this sector due to automation technologies could have far-reaching effects on the quality and delivery of public services. Therefore, it is critical to understand these changes to ensure that adopting automation technologies enhances public service delivery rather than undermining it. In conclusion, the academic exploration of the linkages between automation technologies and the organization of work in the public sector is necessary and timely, given the rapid advancements in automation technologies and their increasing adoption in various sectors.

In sum, we recognize this automated literature review and evidence synthesis methodology to be of immense value for researchers at all stages of their careers. The approach enables the exploration and mapping of virtually any research field using computational methods, offering a systematic and reproducible strategy for reviewing the continually expanding body of research literature.

This method provides an efficient way for established researchers to stay abreast of the latest developments in their field, allowing them to quickly identify new trends, methodologies, or areas of interest. It can also aid in identifying gaps in the existing literature, informing the direction of future research endeavors. For early-stage researchers, the approach can be a valuable tool for

gaining a comprehensive overview of their field of study. It can help them understand their field's key themes, debates, and methodologies and identify the most influential studies and authors. This can be particularly beneficial when defining their research questions or conducting the literature review for their research projects.

Moreover, the programmatic nature of this approach enhances the reproducibility of the literature review process. Using a computational method to review the literature, researchers can provide a clear record of the steps they took, the parameters they used, and their decisions. This transparency enhances the credibility of the literature review. It allows other researchers to replicate the study, test the robustness of the findings, or adapt the method to their research questions. In essence, this automated approach to literature review and evidence synthesis represents a significant advancement in how researchers can navigate, understand, and contribute to their respective fields in the face of the ever-growing research literature.

May this be an opportunity to highlight the experimental nature of unsupervised machine learning methods for literature review, given the exponential growth in the scientific literature in most fields of knowledge. It is pivotal to explore the potential future applications and advancements of the Structural Topic Model (STM) in yielding more profound and comprehensive insights. The possible integration of STM with diverse and robust data sources, such as systematic reviews, can provide a multifaceted and richer perspective, addressing existing limitations and enhancing the quality of outcomes obtained from Natural Language Processing applications to bibliographic data. Thus, the ongoing pursuit to refine and improve the methodologies in leveraging STM, coupled with a diversified array of resources, is paramount to ensure the continued progression and realization of more insightful and beneficial results in subsequent research endeavors.

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Appendix 1. Appendix List of Topics Identified in the Model

Topics and word probabilities in k=30

This appendix contains the results of the labelTopics() function of the stm R package. It contains 10 terms for each word configuration for each topic. For highest probability terms, FREX: Frequency and Exclusivity, lift is a weighting measure that gives more weight to words that appear less frequently in other topics, and a similar weighting measure is score topics estimated using the log frequency of the word divided by the log frequency of the word in other topics.

The interpretation of the contents of the topic is written in parentheses.

Topic 1 Top Words: (Web)

Highest Prob: web, site, content, search, usabl, websit, de, presenc, ontolog, web-bas

FREX: web, site, de, search, usabl, ontolog, content, web-bas, section, presenc

Lift: de, web, site, ontolog, search, web-bas, usabl, section, engin, presenc

Score: de, web, site, content, usabl, websit, search, ontolog, portal, page

Topic 2 Top Words: (Electronic Voting)

Highest Prob: vote, elect, voter, e-vot, elector, imag, ballot, protocol, verifi, experi

FREX: vote, e-vot, voter, ballot, elect, elector, imag, protocol, verifi, procedur

Lift: ballot, vote, e-vot, voter, imag, elector, elect, verifi, protocol, nigeria

Score: ballot, vote, e-vot, voter, elect, elector, imag, protocol, verifi, secur

Topic 3 Top Words: (Boilerplate Topic)

Highest Prob: divid, librari, feder, educ, scienc, refer, uk, email, publish, document

FREX: librari, divid, feder, email, scienc, copi, educ, uk, africa, materi

Lift: librari, copi, email, african, literaci, version, feder, materi, properti, africa

Score: librari, copi, divid, email, feder, educ, africa, scienc, uk, african

Topic 4 Top Words: (Local government website)

Highest Prob: websit, municip, determin, disclosur, variabl, analys, degre, index, sampl, whether

FREX: municip, websit, disclosur, degre, spanish, index, variabl, determin, budget, sampl

Lift: spanish, municip, disclosur, websit, degre, budget, size, score, ministri, index

Score: spanish, websit, municip, disclosur, index, variabl, degre, budget, determin, usabl

Topic 5 Top Words: (Policing and crime)

Highest Prob: function, stage, report, offic, app, polic, conflict, crime, depart, contact

FREX: polic, offic, conflict, stage, function, app, crime, report, contact, depart

Lift: polic, conflict, crime, offic, contact, app, stage, function, trace, report

Score: polic, offic, stage, app, crime, conflict, function, contact, report, depart

Topic 6 Top Words: (Open Government Data)

Highest Prob: platform, ogd, portal, barrier, account, dataset, lack, principl, element, avail

FREX: ogd, platform, portal, barrier, dataset, principl, element, account, releas, lack

Lift: ogd, platform, portal, barrier, dataset, releas, principl, co-creat, ecosystem, element

Score: ogd, platform, portal, barrier, dataset, ecosystem, account, principl, co-creat, releas

Topic 7 Top Words: (Trust, TAM)

Highest Prob: trust, perceiv, intent, accept, behavior, attitud, usag, mobil, determin, construct

FREX: intent, perceiv, trust, attitud, accept, behavior, eas, usag, equat, m-govern

Lift: m-govern, intent, perceiv, tam, trust, eas, equat, predictor, accept, gender

Score: m-govern, perceiv, trust, intent, accept, attitud, tam, behavior, equat, mobil

Topic 8 Top Words: (ID Management)

Highest Prob: mobil, scheme, secur, control, authent, detect, identif, generat, devic, reliabl

FREX: scheme, authent, detect, identif, mobil, signatur, devic, reliabl, entiti, attack

Lift: signatur, scheme, authent, detect, identif, entiti, simul, devic, reliabl, experiment

Score: signatur, scheme, authent, secur, detect, mobil, protocol, attack, devic, identif

Topic 9 Top Words: (Artificial intelligence and recommendation systems)

Highest Prob: recommend, review, techniqu, analyt, intellig, algorithm, ai, field, machin, societi

FREX: recommend, intellig, ai, analyt, algorithm, techniqu, machin, artifici, review, extract

Lift: ai, artifici, recommend, machin, intellig, algorithm, analyt, extract, techniqu, hybrid

Score: ai, recommend, algorithm, intellig, artifici, review, analyt, techniqu, machin, semant

Topic 10 Top Words: (Cybersecurity and Privacy)

Highest Prob: privaci, secur, risk, protect, threat, cyber, person, concern, cybersecur, individu

FREX: privaci, cyber, protect, threat, risk, cybersecur, secur, person, vulner, concern

Lift: cybersecur, cyber, privaci, threat, protect, vulner, risk, foreign, trade, surveil

Score: cybersecur, privaci, secur, cyber, protect, threat, risk, attack, person, surveil

Topic 11 Top Words: (e-Procurement, other business)

Highest Prob: busi, benefit, strateg, custom, cost, procur, share, realiz, oper, object

FREX: custom, strateg, busi, procur, benefit, realiz, e-procur, cost, suppli, failur

Lift: procur, e-procur, custom, strateg, realiz, busi, nigeria, benefit, arrang, suppli

Score: procur, busi, e-procur, benefit, custom, strateg, cost, chain, nigeria, realiz

Topic 12 Top Words: (Boilerplate topic, China?)

Highest Prob: financi, china, central, intern, economi, global, account, chines, econom, regul

FREX: china, financi, central, chines, global, economi, intern, bank, leadership, account

Lift: bank, chines, financi, china, central, leadership, economi, global, intern, transit

Score: bank, financi, china, economi, chines, central, global, intern, leadership, regul

Topic 13 Top Words: (Citizenship, civic, offline)

Highest Prob: peopl, ident, civic, citizenship, offlin, student, individu, becom, power, age

FREX: citizenship, ident, offlin, peopl, student, civic, young, age, movement, regim

Lift: citizenship, young, offlin, ident, school, student, peopl, regim, movement, age

Score: citizenship, ident, peopl, civic, young, offlin, student, movement, inequ, regim

Topic 14 Top Words: (Cloud computing)

Highest Prob: comput, cloud, secur, taiwan, environ, univers, firm, infrastructur, flexibl, technic

FREX: cloud, comput, taiwan, secur, firm, flexibl, univers, australian, australia, softwar

Lift: cloud, comput, taiwan, flexibl, firm, australia, australian, secur, sensit, cooper

Score: cloud, comput, secur, taiwan, firm, flexibl, australian, australia, infrastructur, risk

Topic 15 Top Words: (e-participation, decision making)

Highest Prob: decis, e-particip, decision-mak, participatori, environment, policy-mak, group, map, foster, high

FREX: e-particip, decision-mak, decis, participatori, policy-mak, environment, foster, map, prefer, cognit

Lift: e-particip, policy-mak, decision-mak, participatori, gis, decis, environment, cognit, foster, prefer

Score: e-particip, participatori, decis, decision-mak, policy-mak, environment, gis, cognit, prefer, foster

Topic 16 Top Words: (Health)

Highest Prob: health, record, care, readi, medic, databas, patient, archiv, conclus, preserv

FREX: health, care, patient, record, medic, preserv, readi, archiv, databas, background

Lift: preserv, patient, health, care, medic, archiv, record, readi, background, databas

Score: preserv, health, record, care, readi, archiv, medic, patient, databas, healthcar

Topic 17 Top Words: (Social media and electoral competition)

Highest Prob: parti, twitter, campaign, candid, post, facebook, news, content, elect, messag

FREX: campaign, candid, twitter, facebook, news, parti, post, comment, tweet, messag

Lift: candid, campaign, facebook, twitter, news, tweet, comment, audienc, parti, politician

Score: candid, twitter, campaign, parti, facebook, elect, news, tweet, post, messag

Topic 18 Top Words: (Maturity models in e-Government)

Highest Prob: organiz, capabl, diffus, characterist, matur, dimens, theoret, task, outcom, explain

FREX: diffus, capabl, organiz, matur, characterist, task, contextu, e-gov, guid, theoret

Lift: e-gov, diffus, matur, capabl, contextu, organiz, task, guid, characterist, creation

Score: e-gov, organiz, matur, capabl, diffus, characterist, dimens, task, contextu, theoret

Topic 19 Top Words: (Interoperability)

Highest Prob: stakehold, organis, interoper, standard, egovern, privat, concept, complex, sustain, conceptu

FREX: stakehold, interoper, organis, egovern, standard, privat, conceptu, concept, complex, technic

Lift: egovern, interoper, stakehold, organis, standard, exchang, cooper, privat, logic, technic

Score: egovern, interoper, stakehold, organis, standard, sustain, semant, conceptu, privat, complex

Topic 20 Top Words: (Blockchain, decentralized)

Highest Prob: blockchain, transact, regul, contract, asset, decentr, distribut, trust, ensur, solut

FREX: blockchain, transact, contract, asset, decentr, regul, distribut, exchang, ensur, trust

Lift: blockchain, contract, transact, decentr, asset, regul, distribut, chain, exchang, intermediari

Score: blockchain, transact, contract, regul, asset, decentr, trust, distribut, chain, protocol

Topic 21 Top Words: (e-Services in the European Union)

Highest Prob: measur, european, e-servic, eu, compar, year, benchmark, evolut, index, term

FREX: e-servic, european, benchmark, eu, measur, evolut, union, journal, index, year

Lift: benchmark, e-servic, union, eu, european, europ, journal, evolut, rank, measur

Score: benchmark, e-servic, european, eu, measur, index, journal, union, rank, europ

Topic 22 Top Words: (Employment topic: Skill, train, satisfaction)

Highest Prob: satisfact, employe, channel, motiv, job, questionnair, resist, government, characterist, affect

FREX: employe, satisfact, job, channel, resist, motiv, questionnair, government, skill, train

Lift: job, employe, resist, satisfact, channel, motiv, questionnair, train, skill, mix

Score: job, satisfact, employe, channel, resist, questionnair, train, motiv, skill, organiz

Topic 23 Top Words: (Smart cities)

Highest Prob: urban, plan, smart, infrastructur, compon, architectur, energi, sustain, product, grid

FREX: urban, plan, compon, energi, grid, land, infrastructur, product, spatial, architectur

Lift: grid, land, energi, urban, plan, compon, resili, optim, spatial, climat

Score: grid, urban, smart, plan, energi, land, compon, infrastructur, architectur, resili

Topic 24 Top Words: (Broadband penetration, rural)

Highest Prob: region, program, rural, infrastructur, broadband, deliveri, popul, rate, india, market

FREX: region, rural, broadband, program, deliveri, e-commerc, rate, fund, popul, invest

Lift: broadband, rural, region, e-commerc, program, counti, fund, p, socioeconom, per

Score: broadband, rural, region, program, e-commerc, infrastructur, deliveri, spatial, p, fund

Topic 25 Top Words: (Regulatory issues, law)

Highest Prob: transform, reform, legal, law, legisl, rule, act, court, formal, definit

FREX: reform, transform, legal, court, rule, legisl, law, justic, definit, servant

Lift: court, reform, justic, rule, legal, servant, transform, legisl, right, law

Score: court, transform, reform, law, legal, legisl, justic, rule, civil, servant

Topic 26 Top Words: (Democratic Values and practices)

Highest Prob: democrat, democraci, learn, argu, debat, e-democraci, draw, civic, space, deliber

FREX: democrat, e-democraci, democraci, debat, deliber, crowdsourc, learn, space, civic, forum

Lift: crowdsourc, delib, deliber, forum, e-democraci, debat, democrat, democraci, argument, idea

Score: crowdsourc, democrat, democraci, deliber, e-democraci, delib, civic, forum, debat, learn

Topic 27 Top Words: (Internet of Things)

Highest Prob: smart, big, iot, sustain, transport, thing, urban, traffic, industri, life

FREX: iot, big, smart, transport, thing, sustain, traffic, life, industri, safeti

Lift: iot, transport, thing, smart, big, traffic, water, safeti, sustain, life

Score: iot, smart, big, transport, urban, thing, traffic, sustain, water, industri

Topic 28 Top Words: (Corruption, perception)

Highest Prob: corrupt, econom, associ, societi, control, reduc, greater, evid, percept, negat

FREX: corrupt, greater, moder, negat, estim, percept, associ, econom, reduc, societi

Lift: corrupt, estim, freedom, moder, korea, greater, regress, negat, civil, reduc

Score: corrupt, moder, econom, percept, democraci, societi, negat, civil, estim, regress

Topic 29 Top Words: (Covid-19, pandemic issues)

Highest Prob: collabor, communiti, share, disast, action, covid-19, crisi, resourc, event, monitor

FREX: disast, covid-19, collabor, crisi, communiti, event, action, share, pandem, monitor

Lift: disast, covid-19, crisi, pandem, event, collabor, spread, boundari, communiti, action

Score: disast, collabor, communiti, covid-19, crisi, event, share, action, pandem, monitor

Topic 30 Top Words: (Tax issues)

Highest Prob: tax, modern, format, featur, us, mechan, economi, crucial, phase, necessari

FREX: tax, format, modern, us, crucial, featur, phase, character, necessari, economi

Lift: tax, format, modern, crucial, character, phase, us, featur, long, difficult

Score: tax, modern, format, economi, featur, complianc, phase, crucial, us, character

CHAPTER III - DIGITALIZATION AND THE PUBLIC SECTOR WORKFORCE: A PANEL DATA EXPLORATION OF 20 EUROPEAN COUNTRIES

Abstract

The study of the links between automation technologies and the organization of work has been traditionally conducted by observing the private sector in advanced economies. There needs to be more literature regarding the impact of digital technologies on the public sector workforce. The public sector is a prominent adopter of Information and Communication Technologies (ICT) and commands a massive and diverse workforce. The existing literature has conceptually acknowledged the impacts of digital technologies on public sector workers, but only some empirical approximations of this matter were found. Some factors make this line of inquiry particularly complex: the very nature of the public sector as a non-market, the absence of output prices, data limitations, and measurement challenges. The public sector is not homogeneous in scale or scope across and within countries; it responds to intricate institutional factors, path dependencies, socio-political arrangements, and economic and fiscal constraints. This chapter aims to address this gap in the literature by exploring the relationship between digitalization and selected public employment indicators in European countries at the national level by proposing an identification strategy exploring a relatively novel dataset, the World Bank's Worldwide Bureaucracy Indicators (WWBI), and merging it with the digitalization indices found in the United Nations e-Government Development Index (EGDI). We examine public employment indicators in 20 European countries[2] in six biennial periods from 2008 to 2018. We explore this dataset from three distinct perspectives: first, at the aggregate level, by analyzing the public sector employment as a share of formal employment and the public sector's wage bill as a share of GDP. Second, by analyzing the effects of digitalization on five different occupational classes of the public sector. Third, we analyze the effects of digitalization by the educational tier of the public sector workforce. In aggregate terms, digitalization does not seem to be a labor-saving technology in the European public sector. However, when explored at an occupational level, the data suggest a polarization between high-skill and low-skill occupations and by educational tier, reflecting some of the

[2] The selected countries are Austria, Belgium, Czech Republic, Estonia, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Poland, Portugal, Slovak Republic, Spain, Switzerland, and the United Kingdom.

behavior described in a market context as the effects of automation technologies on labor. Digitalization has a negative and significant impact on the public sector wage bill, suggesting that digitalization allows for the automation of some tasks, reducing the need for human labor in specific functions thus reducing the incidence of wages on total costs. Digitalization could also lead to reorganizing work processes, which might reduce the number of employees needed in some functions. Due to data aggregation, some of these findings might reflect significant differences among public sector occupations. The European public sector is diverse in composition, scope, and mandate, and labor market institutions are embedded in national contexts that have not been considered for this analysis.

Keywords: digitalization, European public sector, panel data, wage bill, e-government index, bureaucracy indicators, public sector occupations, aggregate data

1. Introduction

The impact and effects of technological change on labor markets have been a prevalent topic within academic research in economics, innovation, and organization studies for a relatively extended period. Yet, it continues to present a rich and captivating field for exploration and academic research. Powerful automation technologies such as Information and Communication Technologies (ICT), robotics, and artificial intelligence, initially developed by and for science laboratories and research centers, have become commercial applications adopted by public and private organizations, citizens, and end-users. This constant flow of innovations continues to nourish the research interest in the relationship between automation technologies and labor.

The widespread deployment and adoption of modern technologies, such as automation, digitalization, and robotization, have sparked renewed interest in the scholarly debate surrounding their impact on the organization of work and the workforce. However, most existing conceptualizations and empirical research have been conducted within the private sector context, leaving a noticeable gap in understanding how these technological advancements may affect the public sector workforce. This disparity in research highlights the need for an equivalent debate and investigation into the implications of modern technologies for public sector employees. The public sector, responsible for delivering essential services and implementing policy objectives, is integral to the overall economy and societal well-being. Consequently, understanding how digital

technologies shape the public sector workforce is crucial for ensuring the continued efficiency and effectiveness of government operations.

Within this context, however, the study of the effects of technological change on the public sector workforce has often been overlooked. Most empirical research investigating the impact of innovation, automation, digitalization, and technological change on labor markets has predominantly focused on the private sector in advanced democracies. This research trend has inadvertently led to a significant knowledge gap regarding the relationship between public-sector innovation and its effects on the public-sector workforce. By addressing this knowledge gap, we intend to understand better how technological change via digitalization in the public sector influences employment levels.

The digitalization process is allowing a more specific division of labor into the smallest possible tasks, opening more opportunities for the implementation of self-service solutions, and facilitating scenarios for the co-production and co-creation of public services, turning each citizen and user into "*his or her own administrator, caseworker, and bureaucrat*" (Schou & Hjelholt, 2018), and possibly generating administrative burden of citizens. Co-production and co-creation of public services, meaning the involvement of diverse stakeholders in the different phases of public sector services design and delivery, is far from a novel idea (Khan & Krishnan, 2021; Scupola & Mergel, 2021). Nonetheless, digitally enabled co-production of public services is a subject that is earning the attention of researchers in digital government and is relevant for the argument of this document on encouraging the study of the effects of digital technologies on the public sector workforce. Therefore, it is deemed pertinent and timely to extend the scholarly exploration of the effects of digitalization in the organization of work in public organizations and the potential consequences for the public sector workforce.

In most European economies, the public sector plays a significant role, employing a considerable proportion of a nation's workforce to carry out constitutional functions, deliver public services, implement policy objectives, and manage public organizations. While the impact of modern technologies, such as automation, digitalization, and robotization, on labor has been extensively explored within the private sector, there is a growing need to understand their implications in the public sector.

Investigating the potential consequences and opportunities arising from public sector innovation has been on the research agenda of a diverse group of scholars with varied methodological approaches and scopes of analysis (Arduini et al., 2010; Arundel & Huber, 2013; Cepparulo & Zanfei, 2021; Scupola & Mergel, 2021; Scupola & Zanfei, 2016). The extant literature has conceptually acknowledged the impacts of digital technologies on public sector workers, but few empirical approximations of this matter were found (Andersen et al., 2010; Kim et al., 2021; Lember et al., 2019; Lloyd & Payne, 2019, 2021; MacLean & Titah, 2021; Monteiro & Paiva Dias, 2021).

Some factors make this line of inquiry particularly complex: the very nature of the public sector as a non-market, the absence of output prices, data limitations, and measurement challenges. The public sector is not homogeneous in scale or scope across and within countries. It responds to intricate institutional factors, path dependencies, socio-political arrangements, and economic and fiscal constraints (Demircioglu & Audretsch, 2020). The proportion of public sector employment as a share of total employment among OECD member countries varies considerably. On the lower end of the spectrum, public sector employment in Japan constitutes approximately 6% of total employment. In most European countries, this figure ranges between 12% and 18%, while in the Nordic countries, public sector employment accounts for a significantly higher proportion, reaching up to nearly 30% of total employment (OECD, 2021). The immense scale and economic influence of the public sector are undeniable, the government spending of European countries within the OECD represented over 50% of their respective Gross Domestic Product (GDP) in 2020.

In general, public-sector jobs are often perceived as offering greater job security compared to their private sector counterparts. This perception can be attributed to factors such as the stability of government funding, stronger labor protections, and a lower likelihood of organizational closures or restructuring. As a result, public sector employment tends to attract certain demographics of the workforce (Kopelman & Rosen, 2016). Regarding its composition, the public sector workforce is predominantly composed of women, college-educated individuals, and older workers (Fontaine et al., 2020). This demographic distribution can be attributed to various factors, including the public sector's commitment to equal opportunity, the prevalence of family-friendly policies, and the availability of roles that require advanced qualifications or extensive experience. In some occupations, public sector jobs offer wage premiums compared to private sector

equivalents (Garibaldi et al., 2021), which may further contribute to the attractiveness of public sector employment for these demographic groups. To the best of our knowledge, this is the first attempt to pursue an empirical strategy using panel data to estimate the impact of digital technologies in the public sector workforce of selected European countries.

The pursuit of digital technologies to foster innovation has been on the political and social agenda of the European Union for more than one decade, initially through the signature of member states of the Ministerial Declaration on eGovernment, also known as the Malmö Declaration in 2009, followed by the Tallin Declaration of 2017, and subsequently the Berlin Declaration on Digital Society and Value-based Digital Government of 2020. Cumulative investments in key infrastructure, iterative efforts to implement regional strategies and the effective enactment of digital government programs by European countries have resulted in the leadership of the region in indicators such as the United Nations' E-Government Development Index for measuring digital government performance.

Over the past few decades, the European public sector has experienced incremental transformations as it moves towards the production and provision of its services with the assistance of digital technologies. These advancements have been spurred on by the rapid adoption of smartphones, the widespread diffusion of social media, and the increasing reliance on internet connectivity for information exchange and the design of new transactional channels with the public. On the other hand, there are the fiscal constraints that lead to the pursue economic efficiencies and reduction operational costs. As a result, the interaction between public administrations, citizens, and firms has evolved significantly, fostering greater transparency, accessibility, and responsiveness in the delivery of public services (Arundel et al., 2015; Desmarchelier et al., 2019; Maroto & Rubalcaba, 2005; Tammel, 2017).

This shift towards digitalization in the public sector has not only led to improvements in efficiency and effectiveness but has also raised questions about the implications for employment and the future of work in government organizations (Danziger & Andersen, 2002; MacLean & Titah, 2021). The incremental integration of emerging technologies such as AI, machine learning, and big data analytics has the potential to automate various tasks and responsibilities traditionally performed by public sector employees, meaning that the use of artificial intelligence and algorithms in the public sector contemplates the impacts on the organization of work, and the

potential substitution, transformation, or creation of jobs (Medaglia et al., 2021; A. Meijer et al., 2021; Wirtz et al., 2018, 2021). In addition, digital technologies have allowed the renewed interest of the concept of co-production in public services, in which citizens via digital technologies participate in the diverse steps of the co-creation and co-production of the public service (Lember et al., 2019; A. J. Meijer, 2011, 2012; Yuan, 2019). While this can result in cost savings and streamlined operations, it may also contribute to job displacement and the widening of the skills gap between employees proficient in using digital technologies and those who are not.

As European public sector organizations continue to adopt and implement digital technologies, it is crucial to understand and address the potential consequences of these technologies on the labor force. Policymakers and organizational leaders must consider the implications of automation and AI on employment, skills development, and workforce planning to ensure that the public sector can effectively adapt to the changing technological landscape. By fostering a proactive and inclusive approach to managing digital transformation, the public sector can balance the benefits of technological advancement with the need to maintain a skilled, engaged, and diverse workforce that is prepared to meet the challenges and opportunities of the digital age. As previously discussed, the public sector remains a relatively underexplored area in terms of understanding the impact of technological change on its workforce. Consequently, it is crucial to address this knowledge gap and investigate the effects of digital transformation on the public sector workforce, considering that the "public administration" is considered medium-high in digital intensity (Calvino et al., 2018).

To address the research questions given the available data, we followed the specification strategy consistently found in the literature, the use of panel data to estimate impact of automation technologies on employment (Filippi et al., 2023), even though fixed effects regression has been deemed the standard estimation technique for this type of inquiry (Gözgör et al., 2019), we applied a combination of fixed effects and random effects in our estimations, according to the Hausman test results. Research assessing the overall effects on employment typically utilizes panel data and regression methodologies for their analyses (Hötte et al., 2022), thus informing the methodological selections for this chapter.

In this chapter, we assemble the foundation of our analysis on a constructed data set, a combination of data primarily collected from two sources. The first of these sources is the World

Bank's Worldwide Bureaucracy Indicators. This resource is pivotal in offering a wealth of global insights and data points related to public sector employment and wages, enabling a nuanced understanding of bureaucracy and its varied manifestations across different nations (F. A. Baig et al., 2021).

The second source that significantly contributes to our dataset is the United Nations e-Government Development Index. This index is instrumental in providing extensive data and information regarding the level and quality of online services, telecommunication infrastructure, and inherent human capacity, reflecting the extent and depth of e-government development on a global scale (United Nations, 2022). These sources have been merged, yielding a rich and diversified dataset that acts as the base of our analysis.

Section 2 presents a review of relevant sources that have explored the relationship between automation technologies and connecting it to the public sector context, section 3 elaborates on the research design, data and methods used for this exploration, section 4 discusses findings from the dataset and section 5 offers conclusions, acknowledges limitations, and formulate possible research avenues for further research.

2. Literature review

Over the past 20 years, governments at various levels, including national, regional, and local administrations across the globe, have actively deployed, and implemented digital technologies in their operations. The primary objectives of this digital transformation have been to enhance the quality of public services, streamline operations, and promote cost-effective resource management (Bannister, 2001; Bovens & Zouridis, 2002; Danziger & Andersen, 2002; Fountain, 2001; Layne & Lee, 2001; Moon, 2002). The outcomes of these digital initiatives, however, have varied significantly across different jurisdictions and sectors and the extant literature includes success cases and research on success factors (Gil-García & Pardo, 2005; Kitsing, 2011), but also the description of cases of utter failure (Bolgherini, 2007; Goldfinch, 2007; Holgeid & Thompson, 2013), and some other cases in-between that study mixed results and provide a glimpse of the cultural and institutional intricacies of digital initiatives implementation in the public sector (Bannister & Connolly, 2012; Bélanger & Carter, 2008, 2009; Carter & Weerakkody, 2008; El-Haddadeh et al., 2013).

The integration of digital technologies within public sector operations has facilitated a myriad of benefits, such as increased efficiency, transparency, reduced bureaucratic hurdles, and improved access to essential services for citizens. For example, the introduction of e-government services has enabled people to access critical information, complete transactions, and communicate with public agencies through online portals and mobile applications. These digital channels have provided citizens with greater convenience and autonomy, reducing the need for in-person interactions and minimizing wait times (Cepparulo & Zanfei, 2021).

Despite these potential benefits, the implementation of digital technologies within the public sector has not always yielded the desired results. Some governments have faced challenges in terms of limited resources, inadequate digital infrastructure, or resistance to change service channels and adoption among employees and citizens (Andersen et al., 2012; A. Meijer, 2015; Rana et al., 2017; Savoldelli et al., 2014). Moreover, issues related to data privacy, security, citizens' trust, administrative burden to users, and digital exclusion have emerged as significant concerns that need to be addressed to ensure a successful digital transformation (Aceto et al., 2018; Bannister & Connolly, 2011; Im et al., 2014; Ingrams et al., 2021; Larsson, 2021; Löfgren & Webster, 2020; Madsen et al., 2020).

One notable factor contributing to this digital transformation has been the rapid adoption of smartphones, which has fundamentally changed the way people access information and interact with public services. Smartphones have enabled citizens to access various government services and resources at their fingertips, fostering greater convenience and accessibility. As a result, public administrations have been compelled to adapt their service offerings and communication channels to cater to this increasingly mobile and digitally connected population. In addition to smartphones, the widespread diffusion of social media has played a crucial role in reshaping the interaction between public administrations, citizens, and firms. Social media platforms have provided governments with new avenues for engaging with citizens, disseminating information, and gathering feedback on public services and policies. This enhanced communication and collaboration have led to increased transparency and responsiveness, which are essential for fostering public trust and ensuring the effective delivery of public services (Alam, 2020; Dekker & Bekkers, 2015; Linders, 2012; Picazo-Vela et al., 2012).

As the public sector continues to evolve and adapt to the digital landscape, it is crucial for governments to remain agile and responsive to the evolving needs and expectations of their citizens, who are becoming sophisticated users of digital technologies and expect equivalent level of agility and service delivery satisfaction as found in some private sector services. This includes investing in digital infrastructure, fostering a culture of innovation, and promoting digital literacy among public sector employees. By embracing digital technologies and leveraging their potential, public administrations can enhance the overall quality of public services, strengthen citizen engagement, and better serve the diverse needs of their communities in an increasingly digitalized society.

Digital government research has emerged as a multifaceted and interdisciplinary field of study that encompasses the intersection of various disciplines, including public administration, political science, information systems, economics, computer science, innovation studies, and more. This field seeks to investigate the modernization and optimization of government functions through the utilization of information and communication technologies (ICTs). The interdisciplinary nature of digital government research offers a diverse and robust theoretical and methodological foundation, which in turn, enriches the quality and scope of academic inquiry (Gil-Garcia et al., 2018; Gil-Garcia & Martinez-Moyano, 2007; Scholl, 2007, 2020).

The multidisciplinary approach to digital government research enables scholars to explore complex phenomena, such as the impact of digital transformation on public service delivery, citizen engagement, and the changing dynamics of governance. By drawing upon insights from various disciplines, researchers can develop a more comprehensive understanding of the challenges, opportunities, and implications associated with the adoption and implementation of digital technologies in the public sector. However, the multidisciplinary nature of the field comes with challenges such as the alleged theoretical blur of its methods of inquiry (Bannister & Connolly, 2015; A. Meijer & Bekkers, 2015).

Recent conceptual and operational developments, such as “digital by default”, “government as a platform”, but also the integration of big data, cloud computing and artificial intelligence (AI) applications and decision support systems by public administrations, have led to significant changes in the way public services are designed and delivered (Kim et al., 2021; O’Reilly, 2011; Pencheva et al., 2020; Schou & Hjelholt, 2018). Digitally enabled provision of

public services is changing the public encounter (Lindgren et al., 2019), novel service design is including new actors in the value creation pipeline, adding to the accounted labor input from public officials the "unaccounted" labor inputs from users and digital agents like artificial intelligence algorithms. As eloquently stated by (Bryson et al., 2016):

> "[…] *the new world is polycentric, multi-nodal, multi-sector, multi-level, multi-actor, multi-logic, multi-media, multi-practice place characterized by complexity, dynamism, uncertainty and ambiguity in which a wide range of actors are engaged in public value creation and do so in shifting configurations*." (Bryson et al., 2016, p. 2):

Furthermore, the emergence of digitally enabled co-production and co-creation of public services has fostered greater collaboration between governments, citizens, and other stakeholders. These advancements have revitalized the debate on their impacts on various aspects of public service delivery, including the implications for the labor input provided by the public sector workforce in these new scenarios (Borry & Getha-Taylor, 2019; Khan & Krishnan, 2021; Larsson & Skjølsvik, 2021; Lember et al., 2019; Scupola & Mergel, 2021).

Moreover, the shift towards digitally enabled co-production and co-creation of public services has altered the traditional roles and responsibilities of public sector employees (Andersson et al., 2021; Plesner et al., 2018). This collaborative approach to service delivery requires public sector workers to engage more actively with citizens and other stakeholders via digital channels, fostering greater transparency, trust, and mutual understanding. As a result, public sector employees may need to develop new skills and competencies, such as digital literacy, communication, and problem-solving abilities, to participate in these collaborative processes effectively.

The adoption of AI applications and decision support systems has the potential to transform the public sector by automating various tasks and processes, resulting in increased efficiency and effectiveness. These technologies can help public sector employees make more informed decisions by providing real-time data analysis and insights, streamlining complex tasks, and reducing the risk of human error. However, the increased reliance on AI and automation also raises concerns about the potential displacement of human labor and the need to reskill public sector employees to adapt to these new technologies. Even though, artificial intelligence has been conceptualized since the 1950s, it is just until recent years that the digital government literature has considered its

potential impact on the public sector operations (Criado & Gil-Garcia, 2019; Gesk & Leyer, 2022; Janssen et al., 2020; Osborne et al., 2022; Sousa et al., 2019; van Noordt & Misuraca, 2022; Zuiderwijk et al., 2021).

The potential impacts of digital technologies on public sector workers have been recognized and discussed conceptually within existing literature (Andersson et al., 2021; Kim et al., 2021; MacLean & Titah, 2021; Plesner et al., 2018). There seems to be a limited number of empirical studies that have specifically examined the subject of public employment in recent years, but none have considered the effects of digitalization in their studies (Bettoni & Santos, 2022; Gözgör et al., 2019; Shahen et al., 2020). Several factors make this line of inquiry complex, the very nature of the public sector as a non-market, the absence of prices for outputs, data limitations and measurement challenges.

Most studies that investigate the influence of technology on labor markets predominantly concentrate on the private sector in developed economies. The levels of analysis have been diverse, from the individuals, firms, sector, occupation, and country level (Mondolo, 2022), and the technologies considered usually include industrial robots, artificial intelligence, information and communication technologies, software and others, a technical report by a body related to the European Commission discusses the taxonomy on automation technologies (Sostero, 2020). Recent reviews have attempted to map the trends found in the literature and help to identify existing paradigms, theories and methods used in this exploration (Autor, 2022; Filippi et al., 2023; Hassel, et al., 2022; Hötte et al., 2022; Nardis & Parente, 2021).

However, despite the relatively extensive research conducted in this area, the findings are often regarded as exploratory rather than definitive. This is due to the complex and ever-evolving nature of technological advancements and their varying effects on different countries, industries, and job categories. Four central frameworks are found in the literature, first, the Skill-Biased Technological Change (STBC), alternatively conceptualized as a competition between educational attainment and technological advancement (Goldin & Katz, 2008), provides a compelling explanation for the observed disparities in socio-economic outcomes among distinct educational cohorts, typically delineated as college-educated versus non-college-educated groups, in numerous developed nations. This theoretical framework posits that the escalating demand for highly educated workers, necessitated by the increasing complexity and skill-intensity of contemporary

occupational roles, in conjunction with the relentless progression of technology, significantly contributes to the widening inequality between these educational groups.

Second, the Routine Biased Technological Change (RBTC) hypothesis, also known as the task-polarization model, is an extension of the Skill-Biased Technological Change (SBTC) approach. This model begins by viewing a job as a series of tasks, some of which are better suited to automation technologies, while others are more effectively performed by humans. The advent of computerization and digitalization has significantly altered this dynamic, shifting many tasks traditionally performed by humans to machines. However, there are tasks that cannot be easily automated (Buyst et al., 2018; Goos et al., 2021). These tasks typically lack a rigidly defined script that machines can execute to achieve successful outcomes. Instead, they require a substantial degree of human expertise and judgment providing arguments at why automation technologies tend to complement more educated workers. Caveats do apply, not all tasks considered hard to automate can be classified as high-skill tasks. Some tasks, mostly in the personal services jobs, require dexterity, human communication and common sense require tacit knowledge, the strength of humans, not machines (Acemoglu & Restrepo, 2022).

Thirdly, the New Work and Task Reinstatement approach rectifies certain constraints inherent in the task framework. A fundamental presumption of the task framework is the static nature of work. However, work and its associated tasks are in a state of constant evolution, necessitating the acquisition of new skills and expertise. This dynamic nature of work is evident in the myriad examples of novel jobs and tasks that have emerged in tandem with the adoption of new technologies. Occupations such as drone pilots, community managers, and prompt engineers exemplify the creation of new roles in the contemporary job market. This approach builds on the traditional task model, automation technologies continue to displace workers from existing tasks, but the creation of new tasks can potentially 'reinstate' demand for workers by generating tasks that necessitate human expertise. Therefore, like the education-race model, the balance between task automation and task creation determines the overall impact of technological change on labor demand. If the pace of automation exceeds that of task creation, labor demand decreases. Conversely, if task creation surpasses automation, labor demand increases (Acemoglu & Restrepo, 2019).

Fourth and last among these frameworks consider the role of advanced technologies such as artificial intelligence in labor demand. Even though AI has been theorized and studied for decades, just until few years ago the potential applications of this technology have become more apparent leading to the possible automation of high-skill and some creative tasks, but probably the recent launch of Large Language Models (LLMs), a form of artificial intelligence that use Natural Language Processing techniques to produce text content, computer code, synthetic images and video, and many more, have accelerated the idea of AI as a general purpose technology also challenging the assumption that only routine tasks are at risk of automation (Eloundou et al., 2023; Zarifhonarvar, 2023).

Several factors contribute to the exploratory nature of these analyses. First, the rapid pace of technological innovation makes it challenging for researchers to develop conclusive findings, as the landscape is constantly changing. As new technologies emerge and existing ones evolve, their effects on labor markets may shift, requiring ongoing investigation and adaptation of existing theories and models. Second, the impact of technology on labor markets is often multifaceted and context dependent. The effects of technological advancements may vary across industries, regions, and demographic groups, making it difficult to draw broad, definitive conclusions. Furthermore, the relationship between technology and labor markets is influenced by a range of interconnected factors, including economic policies, institutional factors, social norms, labor market institutions and unions, which add complexity to the analysis (Dauth et al., 2021; Genz & Schnabel, 2021; Lloyd & Payne, 2019, 2021; Parolin, 2020).

Numerous studies have been conducted in the business sector across various European countries to examine the effects of automation technologies and industrial robots on labor. These investigations have yielded mixed results, with some research indicating that automation can lead to increased productivity and job creation (Aghion et al., 2020; Domini et al., 2021), while others suggest the potential for job displacement and wage inequality (Acemoglu et al., 2020; Pouliakas, 2018). In contrast, the impact of Information and Communication Technology (ICT) and artificial intelligence (AI) have reported negative effects on employment, with concerns surrounding job loss for low skilled workers and the increasing demand for highly skilled workers (Balsmeier & Woerter, 2019; Nardis & Parente, 2021).

Lastly, the methodological differences found in the extant literature tend to result in mixed results associated with measuring and quantifying the impact of technology on labor markets. These findings contribute to the exploratory nature of these studies. Researchers often face difficulties in obtaining reliable, comparable, and comprehensive data, as well as in isolating the specific effects of technology from other influencing factors. Empirical studies reviewed by (Filippi et al., 2023) tend to choose between two approximations, on one hand, to estimate the probability of automation, on the other, to estimate the net impact on employment. Studies estimating the net impact on employment in general relied on panel data and regression methods for their analysis (Hötte et al., 2022). Table 4, provides a summary of the studies reviewed by Filippi et al aimed at the estimation of the net impact on employment by diverse level of analysis.

Table 4. Summary Table of Publications Researching Digitalization as an Automation Technology and their Impact on Employment by Level of Analysis

LEVEL OF ANALYSIS	PUBLICATIONS ESTIMATING THE NET IMPACT ON EMPLOYMENT (+ / - / ?)
Global level	Not analysed level
International level	Not analysed level
Continental level	Not analysed level
Country level	The impact of automation technologies is not clear: + Automation technologies in the long run (Autor and Salomons, 2018) ? Automation technologies (e.g., Fu et al., 2021); Artificial intelligence (Mutascu, 2021)
Regional level	The impact of automation technologies is not clear: + Artificial intelligence for middle-skilled workers in manufacturing firms (Xie et al., 2021) - Artificial intelligence for low-skilled workers (Xie et al., 2021)
Labour market	The impact of automation technologies is not clear: + Automation technologies (e.g., Koch et al., 2019)
Industry level	The impact of automation technologies is not clear: + Automation technologies (e.g., Klenert et al., 2020), only in industries exposed to international trade and competition (Aghion et al., 2020b) and in service industries, “making” sectors and complementary sectors (e.g., Mann and Püttmann, 2018); Artificial intelligence in medium-tech industries (Xie et al., 2021)

LEVEL OF ANALYSIS	PUBLICATIONS ESTIMATING THE NET IMPACT ON EMPLOYMENT (+ / - / ?)
	(?) Automation technologies in the manufacturing sector and in "applying" sectors (e.g., Mann and Püttmann, 2018); 0 Automation technologies only change work organisations (e.g., Boavida and Candeias, 2021); Artificial intelligence (Acemoglu et al., 2020a)
Firm level	The impact of automation technologies is not clear: + Automation technologies (e.g.; Bessen et al., 2020); Information technologies (Bessen and Righi, 2019) 0 Automation technologies (e.g., Parschau and Hauge, 2020)
Occupational level	The impact of automation technologies is not clear: + Artificial intelligence, for high-income occupations (Felten et al., 2019) and non-routine work (Tschang and Almirall, 2021) 0 Artificial intelligence (Acemoglu et al., 2020a) Most exposed occupations: office and administrative support, production, and delivery occupations (Vermeulen et al., 2018) Least exposed occupations: healthcare, management, architecture and engineering, academia, and art (Vermeulen et al., 2018)
Worker level	Most exposed workers: less-educated, young, women, and employed in more automatable occupations, especially in manufacturing industries (e.g., Blanas et al., 2019) Less exposed workers: more educated, older workers and men, especially in service industries (e.g., Blanas et al., 2019)
Work activities level	Not analysed level

Source: Filippi et al 2023, the authors provide a comprehensive list of technologies explored such as industrial robots, this table reflects only technologies related to digitalization.

A prevailing conceptualization concerning the public sector is the issue of Baumol's Cost Disease (BCD) (Baumol & Bowen, 1981; Nordhaus, 2008), this economic concept named after the economist William J. Baumol, who observed that productivity growth in labor-intensive sectors, such as education, healthcare, and other public services, tends to lag in comparison with other more technologically advanced sectors. As a result, the costs associated with providing these services continue to rise over time, even as productivity remains relatively stagnant. This creates

a challenge for public sector organizations, which must grapple with increasing costs without the corresponding improvements in efficiency and output that are typically observed in the private sector.

Thus, productivity in the public sector has been assumed flat or unchanging. For decades the usual accounting procedure for measuring productivity in the public sector has been to estimate outputs by using inputs (Dunleavy, 2017). BCD has been a subject of ongoing interest and debate in the literature (Bailey et al., 2016), as it highlights the distinct economic dynamics that differentiate the public and private sectors. This productivity stagnation is attributed to the inherent nature of these services, which rely heavily on human interaction and cannot be easily automated or replaced by technology. However, digitalization is an automation technology that may challenge this assumption.

3. Research design and methods

This chapter delves into the effects of digitalization on the European public sector, emphasizing its impact on the workforce. Digitalization, recognized as a leading automation technology in the European public sector, has the potential to radically alter the delivery of public services. By automating tasks and processes, it can replace functions that once necessitated human intervention. To unravel the intricacies of this transformation, we segmented our analysis across various dimensions: firstly, in aggregate terms and by country to assess the influence of digitalization on public sector employment; secondly, to determine its effect on the sector's wage bill; and thirdly, at the occupational and worker level, to discern its impact based on functional roles and educational tiers. Consequently, we pose the following research questions:

RQ1: How does digitalization influence labor demand in the European public sector, specifically its potential role as a labor-saving technology in the provision of public services?

RQ2: How does the implementation of digitalization lead to efficiency gains in the public sector, especially in the context of reducing operational costs as measured by the wage bill of the public sector?

RQ3: Does the impact of digitalization on the public sector workforce mirror the occupational polarization observed and reported in the private sector, leading to diverging employment dynamics between high-skilled and low-skilled jobs?

To examine the relation between digitalization in the public sector and public employment indicators we estimate three regressions similar to those in (Gözgör et al., 2019) as follows:

$$PublicSectorWorkforce_{i,t} = \beta_0 + \beta_1 EGDI_{i,t} + \beta_2 X_{i,t} + u_{i,t} \quad (1)$$

$PublicSectorWorkforce_{i,t}$ is presented as proxy to study different level of analysis, following the specification strategy consistently found in the literature. At the national level we estimate the impact of digitalization on the *public employment as share of formal employment* and, the public sector *wage bill as percentage of GDP*. In addition, we estimate the impact of digitalization at the occupational level by estimating the effects of digitalization in five occupational tiers (*clerks, elementary occupations, professionals, senior officials, and technicians*), due to data availability the occupational information in each of the five levels reported in the WWBI database is found as *females as share of public paid employees*. As a general observation in the public sector, public employment exhibits a notable tendency to favor specific demographics, including female employees, older workers, and those with higher levels of education (F. A. Baig et al., 2021; Garibaldi & Gomes, 2021). These stylized facts are drawn from the Worldwide Bureaucracy Indicators (WWBI) database. The WWBI is a unique cross-national dataset on public sector employment and wages. The dataset is derived from administrative data and household surveys, thereby complementing existing, expert perception-based approaches.

A third estimation exercise explores the impact of digitalization in the public sector workforce across different educational levels, primary, secondary, and tertiary education. This approach allows for a more comprehensive understanding of how digital transformation influences the demand for various skill sets and qualifications within the public sector. The public sector often employs a substantial proportion of highly educated workers, as many public service jobs require specialized knowledge and skills, such as policy analysis, legal expertise, or technical proficiency. Public sector organizations may, therefore, be more likely to recruit and retain employees with advanced degrees and professional qualifications, contributing to a workforce that is generally more educated compared to the private sector (F. A. Baig et al., 2021; Garibaldi & Gomes, 2021).

As main regressor, $EGDI_{i,t}$ represents the E-Government Development Index in the country i at time t. The index is highly regarded for its consistency and continuation over time since 2001 with the first global benchmarking report for e-government, making it a reliable measure for tracking the progress of e-government development across countries (Febiri & Hub, 2021; Ronaghan et al., 2002).

$X_{i,t}$ is a vector of control variables that include the *log GDP per capita,* an *Indicator of Quality of Government,* and *Urban Population as percentage of total population,* a similar selection of variables were found in the work by (Gözgör et al., 2019) studying effects of globalization in the size of the public sector in developing economies.

Finally, $u_{i,t} = \vartheta_i + \vartheta_t + \varepsilon_{i,t}$, with ϑ_i representing the unobservable effects that vary between the different study units i but do not vary at time t, ϑ_t represents the unquantifiable effects that vary at time t but not between the study units i, and $\varepsilon_{i,t}$, represents the purely random error term (Baltagi, 2021). According to the literature: ϑ_t and ϑ_i correspond to "time-fixed effects", "country fixed-effects" (Gözgör et al., 2019); to verify whether there is unobservable heterogeneity among individuals and if $u_{i,t}$ satisfy all the assumption of a linear model $(\vartheta_i = 0)$, where ϑ_i is a unique fixed effect for each individual – where the unobservable heterogeneity is incorporated into the model's constant, and it is assumed that individual effects are independent from each other – or if ϑ_i is an unobservable random effect where the error varies among individuals but not over time, the Hausman test is thus applied.

In this chapter, the analysis is based on a dataset constructed by selectively merging data primarily from two sources: the World Bank's Worldwide Bureaucracy Indicators and the United Nations e-Government Development Index (F. A. Baig et al., 2021; United Nations, 2022).

Table 5. Description of variables, data sources and codification used for the analysis

Dependent Variables	**Data Source**	**Codification in this chapter**
Public sector employment as a share of form al employment	(WWBI) Version 1.1	psec_sformal_em
Wage bill as a percentage of GDP	(WWBI)	wbill_per_gdp
Females as a share of public paid employees by occupation (Clerks)	(WWBI)	fpu_em_clerks
Females as a share of public paid employees by occupation (Elementary occupation)	(WWBI)	fpu_em_elem_ocu pation

Dependent Variables	Data Source	Codification in this chapter
Females as a share of public paid employees by occupation (Professionals)	(WWBI)	fpu_em_professional
Females as a share of public paid employees by occupation (Senior officials)	(WWBI)	fpu_em_senior_official
Females as a share of public paid employees by occupation (Technicians)	(WWBI)	fpu_em_technician
Individuals with primary education as a share of public paid employees	(WWBI)	pri_ed_sppaid_em
Individuals with secondary education as a share of public paid employees	(WWBI)	sec_ed_sppaid_em
Individuals with tertiary education as a share of public paid employees	(WWBI)	ter_ed_sppaid_em
Independent Variables		
E-Government Index	United Nations EGDI	egov_index
Log (GDP per capita)	World Bank World Development Indicators (WDI)	gdp_percap
ICRG Indicator of Quality of Government (icrg_qog) **Variable scaled from 0 to 1, higher values indicate higher quality of government, assessment include 'corruption', 'law and order' and 'bureaucracy quality'.**	The Quality of Government Institute at University of Gothenburg	icrg_qog
Urban Population as percentage of total population	World Bank World Development Indicators (WDI)	upop

The panel dataset assembled includes 20 European countries[3] and comparable cross-national information for covering six biennial periods from 2008 to 2018. Given the occurrence of missing values in the dataset some countries were dropped from the data frame, however imputation techniques aided to "rescue" some of the missing data (Moritz & Bartz-Beielstein, 2017). The following table summarizes the dependent and independent variables used for this analysis.

[3] Austria, Belgium, Czech Republic, Estonia, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Poland, Portugal, Slovak Republic, Spain, Switzerland, and the United Kingdom.

Table 6: Summary Statistics of the Merged Dataset

Statistic	N	Mean	St. Dev.	Min	Max
Females as a share of public paid employees by occupation (Clerks)	120	0.000	1.000	-2.389	1.764
Females as a share of public paid employees by occupation (Elementary occupation)	120	-0.000	1.000	-3.325	1.906
Females as a share of public paid employees by occupation (Professionals)	120	-0.000	1.000	-2.761	2.016
Females as a share of public paid employees by occupation (Senior officials)	120	0.000	1.000	-2.629	3.280
Females as a share of public paid employees by occupation (Technicians)	120	-0.000	1.000	-3.196	1.724
Individuals with primary education as a sha re of public paid employees	120	0.000	1.000	-1.113	4.031
Individuals with secondary education as a s hare of public paid employees	120	-0.000	1.000	-1.719	2.450
Individuals with tertiary education as a shar e of public paid employees	120	-0.000	1.000	-2.201	2.214
Public sector employment as a share of form al employment	120	-0.000	1.000	-1.644	2.360
Wage bill as a percentage of GDP	120	-0.000	1.000	-2.150	2.064
United Nations E-Government Index	120	-0.000	1.000	-2.051	2.098
Log (GDP per capita)	120	14.298	0.480	12.609	14.938
Urban population (% of total population)	120	0.000	1.000	-2.789	1.308
ICRG Indicator of Quality of Government	120	0.000	1.000	-1.554	1.728

Source: Descriptive statistics for Normalized Panel Dataset created in stargazer package for R programming language environment.

One key limitation of the $EGDI_{i,t}$ is the lack of a user-centric and demand-side approach in its methodology. The index primarily focuses on the supply-side aspects of e-government, such as the availability of online services, infrastructure, and human capital, while largely overlooking the user experience and the actual uptake of these services by citizens. This omission can lead to an incomplete understanding of a country's e-government performance, as it does not account for factors such as user satisfaction, accessibility, and the overall effectiveness of digital services in meeting citizens' needs (Arduini et al., 2010; Distel & Becker, 2017; Hansen et al., 2018; Hyytinen et al., 2022; Reissig et al., 2022; Yera et al., 2020). Nonetheless, the tenets of user-centricity, accessibility, and user satisfaction have been analyzed in a European context. Leading to a concentrated effort to make digital services more user-friendly, and accessible to all individuals regardless of their circumstances, and ensuring the users' experiences with these services are satisfactory and productive (Capgemini et al., 2016).

The initial data wrangling process for the raw data involved a detailed examination and treatment of the World Wide Bureaucracy Indicators (WWBI) database. The primary focus was on selected variables pertinent to the research, with an emphasis on the EU countries. The initial phase included loading the dataset and performing extensive data cleaning and manipulation. This involved transforming variable types, renaming variables, and managing date-time conversions to ensure data consistency and reliability. Missing values within the dataset were addressed through comprehensive imputation, focusing on countries with missing data points, to develop a complete and accurate dataset. Visualization tools were used extensively to examine data distributions, detect anomalies, and discern patterns in the dataset.

Subsequently, the WWBI dataset underwent filtering processes to retain only the chosen variables and data related to EU countries. The processed and cleaned dataset was saved for further use in subsequent analyses and was merged with other relevant databases, such as OECD, the processes have been documented in a version control repository. This meticulous data wrangling process was crucial for establishing a solid foundation for the ensuing research and analyses, ensuring that the subsequent findings and conclusions drawn are based on accurate, reliable, and comprehensive data. The resultant dataset is pivotal for the overall robustness and validity of the chapter research outcomes.

The merging process was meticulously executed with the aim of consolidating the imputed WWBI dataset with other relevant datasets to create a unified master dataset. This dataset is pivotal for conducting rigorous econometric models. The process involved aligning the datasets on common identifiers, ensuring the coherent integration of variables from different sources. Special attention was given to the integrity and completeness of the data, with a focus on including countries with substantial and reliable data points.

The panel dataset underwent rigorous visualization and inspection processes to affirm its integrity and readiness for subsequent analyses. Detailed structural views, summary statistics, and missing value visualizations were generated to provide insights into the dataset's characteristics and completeness. These processes were pivotal in identifying potential issues and anomalies in the dataset, thereby ensuring the reliability and validity of the subsequent analyses involving this panel dataset.

For purposes of data management, documentation, reproducibility and version control (Bryan, 2018; Gentleman & Temple Lang, 2007; Handel et al., 2021), a GitHub repository was created and has been maintained in following link: https://bit.ly/3UoscNJ. For a more in-depth understanding and detailed list of the data sources utilized, it is recommended to consult the WWBI codebook and the accompanying explanatory note (M. F. A. Baig et al., 2023), this document is also in the GitHub repository. As detailed in the codebook, the differentiation between public and private sector employees is primarily established through a specific question regarding the sector of employment. This methodology applies to most countries included in the study.

4. Findings

Table 7 presents the results of two different regression models, both estimated using aggregate-level data. The dependent variables are (1) *Public Sector Employment as a share of formal employment* and (2) *Wage Bill as a percentage of GDP*.

For the first model, the results show a positive and significant estimate for the E-Government Index, the coefficient is 0.138 and significant at the 1% level for the relationship with Public Sector Employment as a share of formal employment, this implies that a one-unit increase in the E-Government Index is associated with a 0.138-unit increase in the public sector employment as a share of formal employment, holding other variables constant. However, this indicator is calculated as a proportion of formal employment, which implies that it may be sensitive to significant fluctuations in the share of private sector employment. In other words, if there are considerable changes in the proportion of jobs within the private sector, this could potentially impact the overall representation of public sector employment in relation to formal employment. Consequently, the indicator's ability to accurately capture the dynamics of public sector employment may be affected by such variations in the private sector labor market.

For the variable *Log (GDP per capita)*, the coefficient -0.902 suggests an inverse relationship between GDP per capita and the share of public sector employment in formal employment. This could imply that as countries become wealthier (as indicated by an increase in GDP per capita), they tend to have a smaller proportion of their formal employment in the public sector. It is also worth considering that the influence of EU policy recommendations. Some EU countries, especially those part of the Eurozone, have previously been advised to adopt austerity

measures, which included limitations in the public sector expansion. However, the exact reasoning behind this needs further investigation. This is statistically significant at the 1% level.

As for the *Indicator of Quality of Government*, the coefficient is -0.554 and significant at the 5% level. This indicates that a one-unit increase in the quality of government is associated with a 0.554-unit decrease in public sector employment as a share of formal employment, holding other variables constant. There was no significant relationship found for the variable *Urban Population*.

Model 1 adopts a fixed effects approach, as evidenced by the significance of the c^2 value from the Hausman test. This indicates that the time effects are unique for each country under study. Appendix 2 presents the model's coefficients, revealing that every country has a positive and significant coefficient. This suggests that each country possesses a distinct constant, which is directly related to public sector employment.

Table 7. Aggregate Level: Public Sector Employment as Share of Formal Employment & Wage Bill as % of GDP

	Dependent variable	
	Public Sector Employment as share of formal employment (1)	Wage Bill as percentage of GDP (2)
Intercept		-0.002
		(0.036)
E-Government Index	0.138***	-0.146***
	(0.050)	(0.053)
Log (GDP per capita)	-0.902***	-0.410
	(0.297)	(0.264)
Indicator of Quality of Government	-0.554**	-0.096
	(0.257)	(0.273)
Urban population (% of total population)	-0.043	0.010
	(0.037)	(0.025)
Observations	120	100
R^2	0. 177	0.132
F Statistic	5.160***	3.609***
c^2 (Hausman Test)	25.193***	3.890
|F (Wooldridge's first-difference test)	3.8413**	1.696

Note: p < 0.01 ′***′, p < 0.05 ′**′, p < 0.1 ′*′
Source: Table created in stargazer package for R programming language.

As for the second model in Table 7, estimating the relationship with the dependent variable *wage bill of the public sector as share of GDP,* the EGDI coefficient is -0.146 and significant at the 1% level, this implies that a one-unit increase in the E-Government Index is associated with a 0.146-unit decrease in the wage bill as a percentage of GDP, holding other variables constant. This relationship may also be affected by austerity measures and other fiscal policies adopted by some European countries in the aftermath of the Global Financial Crisis of 2008, precisely the initial year of the dataset explored and that may have impacted this indicator due to a restructuration in the European public sector. An alternative explanation of these estimations could be productivity and efficiency gains of digitalization that could probably affect labor costs in rendering of public sector services as evidenced in a negative and significant relationship with the public sector wage bill.

However, it is important to consider that this indicator is calculated as a proportion of formal employment, which suggests that it could be sensitive to substantial fluctuations in the share of private sector employment. In other words, significant changes in the distribution of jobs within the private sector could potentially influence the overall representation of public sector employment relative to formal employment. As a result, the indicator's capacity to accurately capture the dynamics of public sector employment might be affected by such variations in the private sector labor market. Given this potential sensitivity, it is essential to interpret the results with caution and acknowledge the limitations of using an indicator based on the proportion of formal employment. Further research and analysis may be necessary to fully understand the relationship between the E-Government Index and public sector employment, particularly considering the possible effects of private sector employment fluctuations on this relationship. This could involve exploring alternative indicators, methodologies, and datasets with more granularity of the data that better account for the incredibly diverse aspects of public sector occupations and tasks and the impact of automation technologies in each of them.

Additionally, these results are based on the regression model provided, and the relationship could change when different variables or controls are included in the analysis. As for the other variables, the *Log (GDP per capita, Indicator of Quality of Government* and *Urban population as share of total population* no significant relationship is evidenced in model 2.

The R-squared values for both models are relatively low (0.177 for Model 1 and 0.132 for Model 2), suggesting that the independent variables in the models explain a limited amount of the variation in the dependent variables. However, the F-statistics for both models are significant at the 1% level, indicating that the models are statistically significant.

Contrary to model 1, in model 2 the regression is carried out applying the first difference estimator to correct the existing serial magnitude and, additionally, the presence of fixed effects in the model is ruled out. However, although the intercept is equal in magnitude for all the countries studied, it is not significant.

Model (2) in Table 7 examines the relationship between *E-Government Index* and the public sector wage bill as share of GDP, the -0.146 and significant at the 1% level. This finding implies that a one-unit increase in the E-Government Index is associated with a 0.146-unit decrease in the wage bill as a percentage of GDP, assuming other variables are held constant.

However, it is crucial to consider that this relationship may be influenced by austerity measures and other fiscal policies adopted by some European countries in the aftermath of the Global Financial Crisis of 2008, which coincides with the initial year of the dataset explored. These policies could have impacted on the wage bill indicator due to restructuring efforts in the European public sector. An alternative explanation for these estimations could be the productivity and efficiency gains achieved through digitalization, which might affect labor costs in the delivery of public sector services. This interpretation is supported by the observed negative and significant relationship between the E-Government Index and the public sector wage bill. In essence, as digitalization advances within the public sector, it may lead to reduced labor costs, resulting in a lower wage bill as a share of GDP.

Given the potential influence of external factors such as austerity measures and fiscal policies, it is essential to interpret these results with caution and consider the broader context when assessing the impact of digitalization on the public sector wage bill. Further research may be necessary to disentangle the effects of digitalization from other factors shaping the wage bill dynamics and to better understand the mechanisms through which digitalization contributes to efficiency and productivity gains in the public sector.

Table 8 presents the results of five different regression models, each estimated using the same set of independent variables but with different dependent variables related to occupational

functions. The dependent variables are (3) Clerks, workers that perform functions related to recording, organizing, storing, computing, and retrieving information (this classification includes occupations in customer services roles, clerical support, and keyboard clerks), (4) Elementary Occupations, associated functions involve the performance of simple and routine tasks that may include the use of hand-held tools and considerable physical effort, (5) Professionals, possess specialized stock of knowledge, apply scientific or artistic concepts and theories, this classification includes health, teaching, and business professionals, (6) Senior Officials are those whose role is to plan, direct, coordinate and evaluate the overall activities of public organizations, this classification includes chief executives, legislators, and managers of any kind, and (7) Technicians are personnel who perform technical and related tasks connected with research and the application of scientific or artistic concepts, operational methods and government or business regulations[4].

Table 8. By Occupational Function: Five Occupational Levels

	Dependent variable				
	Clerks (3)	Elementary Occupations (4)	Professionals (5)	Senior Officials (6)	Technicians (7)
Intercept				5.117	
				(3.903)	
E-Government Index	0.004	0.135**	0.263***	0.396***	-0.336***
	(0.054)	(0.065)	(0.063)	(0.087)	(0.066)
Log (GDP per capita)	-0.254	0.541	-0.116	-0.494	1.229***
	(0.320)	(0.390)	(0.375)	(0.376)	(0.396)
Indicator of Quality of Government	-0.478*	-0.432	0.233	0.113	-0.173
	(0.277)	(0.338)	(0.325)	(0.246)	(0.343)
Urban population (% of total population)	0.021	0.001	-0.015	0.034	0.033
	(0.040)	(0.049)	(0.047)	(0.067)	(0.050)
Observations	120	120	120	120	120
R^2	0.047	0.071	0.176	0.163	0.262
F Statistic	1.175	1.841	5.140	22.338***	8.522***
c^2 (Hausman Test)	11.959**	12.303*	9.852**	4.096	10.843**
F (Wooldridge's first-difference test)	5.819**	4.7890**	5.705**	5.642**	19.678***

Note: p < 0.01 ′***′, p < 0.05 ′**′, p < 0.1 ′*′
Source: Table created in stargazer package for R programming language.

[4] The level of aggregation is defined in the Worldwide Bureaucracy Indicators Codebook.

The model (3) in this table analyzes the relationship between clerical occupations and the E-Government Development Index, only the *Indicator of Quality of Government* was significant, given the statistical significance at the 10% level, for a unit increase in this variable, the model predicts a decrease of −0.478 units in the dependent variable, holding all other variables constant. This could suggest that better governance may lead to more efficient administrative processes, requiring fewer clerks, or perhaps there's a shift in jobs with better governance. The exact reasoning would need further investigation and context. None of the rest of coefficients estimated for this model are significant, so we pass to discuss the other models presented in the Table.

Instead, models 4, 5, and 6 in the Table 8 estimate a positive and significant relationship between the *E-Government Index* and the employment of Elementary Occupations, Professionals, and Senior Officials. In contrast, model 7 estimates a negative relationship between the *E-Government Index* and employment of Technicians, suggesting that an increase in the E-Government Index may be associated with a decrease in the demand for Technicians within the public sector.

These findings highlight the complexity of the impact of digitalization on the public sector workforce, as different occupational groups exhibit distinct patterns of association with the E-Government Index. While the positive relationship observed for Elementary Occupations, Professionals, and Senior Officials suggests that digitalization may contribute to increased demand for these types of workers, the negative relationship found for Technicians indicates that their demand may decline as the E-Government Index increases. The positive relationship identified for Elementary Occupations, Professionals, and Senior Officials could potentially be interpreted as a reflection of the increased demand for these roles in the wake of digitalization. The introduction and subsequent advancement of digital technologies might require more of these types of roles to be filled for their successful implementation and management.

Conversely, the negative correlation observed for Technicians suggests a contrasting narrative. As the E-Government Index rises, indicating a higher degree of digitalization, the demand for technicians may decrease. This could possibly be due to automation and advanced technologies that can perform tasks previously assigned to Technicians, or a shift in the skill sets required in a more digital environment. This implies that while digitalization may present new opportunities, it may also pose challenges for certain sectors of the workforce.

However, when we look at the *log(GDP per capita)* in Model (7), we notice that the coefficient is statistically significant. There is a 1.229-unit increase in the share of technicians within the public sector for every one-unit increase in the *log(GDP per capita)* while keeping everything else constant. This implies that as the economies of observed sample of countries grow the composition of their public sector workforce changes towards more technical roles. This may suggest various underlying factors. As economies progress, there is a greater need for technical expertise to tackle the intricacies of modern governance, research, and the application of scientific or artistic concepts. Nonetheless, this stark contrast between the E-Government variable and the logged GDP per capita is the opportunity to call for further studies exploring these relationships.

In Table 8, all models, except for Model 6, exhibit fixed effects, as detailed in Appendix 2. The intercepts for Models 3 and 5 are positive, while they are negative for Model 4. However, these intercepts are not statistically significant in any of these models. For Model 7, the intercept is both significant and negative, indicating an average decline in Technician jobs that is not captured by the model's independent variables. In contrast, Model 6 demonstrates variable effects, suggesting that the error tied to each country is not correlated with the other independent variables. Its intercept is positive, though not statistically significant.

The classification of occupations as presented -Clerks, Elementary Occupations, Professionals, Senior Officials, and Technicians- can be viewed as a spectrum of roles that require varying levels of skills and expertise. At one end, Clerks and Elementary Occupations typically involve more routine tasks, and these jobs may require less specialized knowledge and skills. At the other end, Professionals and Senior Officials represent roles that require higher levels of education, specialized knowledge, and decision-making skills. Technicians are positioned in the middle of this spectrum. These jobs typically require a mix of practical and theoretical knowledge, often obtained through vocational or technical education. Arguably this estimation may reflect the task polarization model found in the literature. The task polarization model predicts that computerization spurs a “polarization” of job growth into traditionally high-wage and traditionally low-wage occupations at the expense of the middle tier.

For primary education, the analysis investigates the extent to which digitalization affects the need for workers with basic skills and qualifications. As digital technologies increasingly automate routine tasks, the demand for employees with only primary education may potentially

decline, as their skill sets become less relevant to the changing public sector landscape. Regarding secondary education, the analysis examines how digitalization influences the demand for workers with intermediate skills and qualifications. This group may be particularly vulnerable to the effects of digital transformation, as their skill sets often fall between high-skilled and low-skilled occupations, which could experience significant shifts in demand due to automation and technological advancements. Lastly, the analysis explores the impact of digitalization on the public sector workforce with tertiary education, focusing on highly educated workers who possess advanced degrees and specialized expertise. This group may be expected to benefit from digital transformation, as their advanced skill sets are likely to be in higher demand to manage, develop, and implement digital technologies within public sector organizations.

Table 9. Individuals with Primary, Secondary or Tertiary Education as share of public paid employees

	Dependent variable		
	Primary Education	Secondary Education	Tertiary Education
	(8)	(9)	(10)
Intercept	-0.048**	-0.083**	4.110**
	(0.024)	(0.022)	(1.931)
E-Government Index	-0.123***	-0.087***	0.223***
	(0.035)	(0.032)	(0.033)
Log (GDP per capita)	0.351**	-0.146	-0.397**
	(0.176)	(0.162)	(0.185)
Indicator of Quality of Government	0.244	-0.271	0.332**
	(0.181)	(0.167)	(0.145)
Urban population (% of total population)	0.010	0.015	-0.053**
	(0.017)	(0.015)	(0.025)
Observations	100	100	120
R^2	0.138	0.099	0.357
F Statistic	3.810***	2.615**	63.830***
c^2 (Hausman Test)	0.548	4.224	7.955
F (Wooldridge's first-difference test)	0.048	0.010	4.57**

Note: p < 0.01 ′***′, p < 0.05 ′**′, p < 0.1 ′*′
Source: Table created in stargazer package for R programming language.

The model 8 in Table 9 estimates the relationship between the educational tier and the selected regressors. For the *E-Government Index*, the coefficient is -0.123 and significant at the

1% level. This implies that a one-unit increase in the *E-Government Index* is associated with a 0.123-unit decrease in the proportion of *individuals with primary education as a share of public paid employees*, holding other variables constant.

When examining the relationship between the *log(GDP per capita)* and educational attainment levels among public sector employees in the selected countries, different patterns emerge for primary and tertiary education. Model (8) shows that a one-unit increase in the log(GDP per capita) associated with a 0.351-unit increase in the share of public sector employees with primary education. However, in model (10), the same increase in the *log(GDP per capita)* leads to a 0.397-unit decrease in the share of those with tertiary education. The upward trend for primary education in wealthier nations could be due to a range of entry-level or non-specialized roles within their public sectors, or a higher retention rate of older employees who entered the workforce when primary education was the norm. Conversely, the declining proportion of employees with tertiary education in more affluent countries could be a result of individuals being drawn to the private sector, where they may find more lucrative opportunities or better career advancement prospects. Alternatively, richer countries may place a higher emphasis on skills and experiences over academic credentials in their public sector hiring practices. Further analysis and research would be necessary to understand the underlying causes and dynamics behind these findings.

Model 10 estimates a positive and significant relationship between workers with tertiary education and the *E-Government Index*. The coefficient is 0.223 at a 1% significance level. This relationship may evidence what was discussed above about the similar pattern of polarization as seen in the literature for the effects of automation technologies in the private sector in which workers with higher education attainment, a proxy for high skills, tend to be favored by the implementation of diverse automation technologies. Regarding the relationship between individuals with tertiary education and the indicator of *Quality of Government*, the relationship is positive and significant at a 5% level.

In model 8 with independent variable individuals with primary education as a share of public paid employees, the R^2 value of 0.138 indicates that the independent variables in this model explain approximately 14% of the variation in the proportion of primary education. The F-statistic value of 3.81 (significant at the 1% level) implies that the model is statistically significant, and the independent variables together significantly impact the proportion of primary education.

Model 9 with independent variable individuals with secondary education as a share of public paid employees the adjusted R^2 value of 0.099 indicates that the model's explanatory power is weak after accounting for the number of independent variables. As for the F-statistic, it has a value of 2.615 (significant at the 5% level) suggesting that the model is statistically significant, and the independent variables together significantly impact the proportion of individuals with secondary education.

For model 10, the R^2 value of 0.357 indicates that the independent variables in this model explain about 35.7% of the variation in the proportion of tertiary education. The F-statistic value of 63.83 (significant at the 1% level) implies that the model is statistically significant, and the independent variables together significantly impact the proportion of tertiary education. All models in **Error! Reference source not found.** present random effects, implying that there are no individual effects. However, serial correlation is only observed in models 8 and 9, so the models are estimated in first difference to correct for time disturbances.

The Skill-Biased Technological Change (SBTC) hypothesis argues that technological changes increase the demand for skilled labor relative to unskilled labor. This is because new technologies often require more complex tasks and problem-solving abilities, which are typically associated with higher levels of education.

As for the estimations of Table 8, where the level of analysis focused on public sector occupations aggregated in five tiers, the findings of this analysis underscore the potential complexity of digitalization's impact on the public sector workforce, as different occupational groups display varying patterns of association with the E-Government Index. The positive relationship observed for Elementary Occupations, Professionals, and Senior Officials implies that digitalization may contribute to increased demand for these categories of workers. In contrast, the negative relationship discovered with Technicians suggests that their demand may decline as the E-Government Index increases. This estimation could arguably reflect the task polarization model, which is prevalent in literature. A previous exercise with a similar dataset and assumptions hinted at a similar pattern (Aguilera Castillo, 2021).

In the context of the public sector workforce, the observed patterns of association between digitalization and various occupational groups suggest that the task polarization model may be applicable, with some workers benefiting from digitalization's impact on their occupations while

others face potential challenges or job losses. Nonetheless, the workforce is more diverse than these five levels, it would be pertinent to curate a dataset with more granular occupational information to capture the nuances and hopefully estimate with better accuracy the impacts and effects of digitalization efforts in the European public sector workforce. When examining the impact of digitalization on the workforce, aggregated data on overall employment may mask significant disparities between different occupational groups or skill levels. By focusing only on the aggregated data, researchers may overlook the distinct experiences and challenges faced by specific groups of workers, leading to an incomplete understanding of the issue at hand.

The results of Table 9, provide a different angle of analysis to examine the available data. A similar pattern of polarization is identified by educational tier, keep in mind that the public sector in general tends to hire high-skill workers. The estimations of Table 9 corroborate previous insights that public sector employment may mirror the private sector as regards as the polarization effects of technological change in the workforce. The results presented in Table 9 highlight the importance of considering the polarization effects of technological change on the public sector workforce.

Further research in this area can help to deepen our understanding of these dynamics and inform the development of effective strategies to promote a more inclusive and resilient labor market for public sector workers. The findings discussed above are consistent with the extant literature for the private sector, basically the effects of automation technologies on labor are far from conclusive and should lead to further analysis and improve techniques for inquiry.

Regarding Research Question 1, we found that that digitalization, when considered in aggregate terms, does not function as a labor-saving technology within the European public sector. This implies that the overall impact of digitalization on public sector employment does not lead to a significant reduction in the demand for labor across the board. Instead, the effects of digitalization on public sector workforce dynamics might be more nuanced, with varying outcomes for different occupational groups or skill levels. However, as seen in the results for model 2 in table 5, digitalization is strongly and negatively correlated with the public sector wage bill. An observation that merits further inquiry.

As regards Research Question 2, we found that digitalization leads to efficiency gains in the public sector through the reduction of operational costs, as evidenced by the decrease in the wage bill of the public sector. The adoption and implementation of digital technologies can

streamline various processes, eliminate redundancies, and minimize transaction costs, ultimately resulting in improved operational efficiency and cost savings for public sector organizations. This enhanced efficiency can be attributed to factors such as the automation of repetitive tasks, improved data management and accessibility, and the ability to leverage advanced analytical tools to support evidence-based decision-making. Moreover, digitalization may facilitate more effective communication and collaboration among public sector employees and stakeholders, further contributing to overall productivity gains.

As for Research Question 3, the impact of digitalization on the public sector workforce mirrors the occupational polarization observed and documented in the private sector. The adoption of digital technologies appears to lead to a similar pattern of polarization characterized by a divide between high-skilled and low-skilled jobs. However, according to our data, this polarization does not apply uniformly across all occupational categories within the public sector. Specifically, we found that for clerical jobs our estimates were not significant, thus hinting that in the public sector clerical occupations do not exhibit the same polarization as observed in other occupational levels analyzed. This discrepancy may be due to unique characteristics of public sector employment, or the nature of tasks performed by clerical workers, which may be less susceptible to the polarizing effects of digitalization. Alternatively, it could be attributed to institutional factors, such as regulatory constraints or public sector hiring practices that differ from those in the private sector. In addition, clerical workers in the public sector must apply discretionary powers, thus their functions are not necessarily routine but take a case by case, citizen by citizen approach to serve. For a recent discussion on automation technologies, discretionary powers and public service logic please refer to the following authors (Busch et al., 2018; De Boer & Raaphorst, 2023; Ranerup & Henriksen, 2022).

5. Discussion and conclusions

Different levels of analysis to the constructed dataset to analyze the relationship between public sector workforce variables against a set of regressors resulted in variegated but stimulating estimations. While our findings are far from conclusive, they echo the mixed results found in existing literature regarding the relationship between the private sector workforce and automation technologies. In the public sector workforce, we discovered similar patterns of both positive and

negative effects that digitalization has on employment dynamics. These mixed findings highlight the complexity of the relationship between digitalization and its impact on labor markets, as the consequences of adopting automation technologies appear to vary across different sectors, occupational groups, and contexts. This diversity of outcomes suggests that a one-size-fits-all approach to understanding the effects of digitalization on workforces may be insufficient, and that more nuanced, context-specific investigations are required. Such contrasting results emphasize the need for further research to understand the underlying factors driving these relationships and to provide insights into how digitalization may be reshaping the public sector workforce across various occupational groups.

Nonetheless, the findings we present have important implications for research, policymakers and public sector organizations seeking to adapt to the changing landscape of work in the digital era. Understanding the polarization effect within the public sector can inform strategies to address workforce development, training, and education to ensure that employees possess the necessary skills and qualifications to thrive in a rapidly evolving labor market. Moreover, these insights can guide the development of policies aimed at mitigating the potential negative consequences of polarization, such as rising income inequality and the displacement of middle-tier workers.

Polarization raises several intriguing questions and possible avenues for further research. For instance, researchers could explore the specific mechanisms through which technological advancements influence public sector labor markets in a polarizing manner. Are there unique aspects of digitalization that disproportionately affect middle-skilled jobs in the public sector, or are there common underlying factors driving these trends for both the public and the private sector?

As for limitations in our study and approach, we acknowledge the existence of data limitations, despite the recent policy developments promoting Open Government Data in Europe, the granularity of our dataset remains relatively limited. When examining the impact of digitalization on the workforce, relying solely on aggregated data concerning overall employment can potentially conceal significant disparities that may exist between different occupational groups or skill levels. By focusing exclusively on aggregated data, researchers might inadvertently neglect the unique experiences and challenges faced by specific groups of workers. This oversight could result in a less comprehensive understanding of the issue at hand, ultimately limiting the accuracy

and generalizability of the findings. To address these limitations, future research should seek to incorporate more granular data sources that allow for a more detailed examination of the effects of digitalization on various occupational groups and skill levels. By doing so, researchers will be better equipped to identify and understand the diverse ways in which digitalization impacts different segments of the workforce.

An additional limitation of our study is the exclusive focus on the supply side of digital government. To obtain a more holistic understanding of the impact of digitalization on the public sector workforce, it would be beneficial to complement the EGDI with additional indicators that capture the user-centric and demand-side aspects of e-government. For instance, incorporating measures such as user satisfaction, digital literacy, and the adoption rates of digital services could provide a more comprehensive understanding of a country's e-government performance. This broader perspective would offer valuable insights into how effectively digital services are being received and utilized by the public, and the extent to which these services are meeting the needs and expectations of citizens. By accounting for both the supply and demand sides of e-government, researchers can gain a more nuanced understanding of the various factors influencing the adoption and impact of digital technologies in the public sector. This, in turn, will enable the development of more informed and effective policymaking and strategies for digital transformation. Future research should consider incorporating these additional demand-side indicators and examining the interplay between them and the supply-side factors captured by the EGDI. This will help to create a more accurate and complete picture of the effects of digitalization on the public sector workforce.

The public sector workforce is fundamental in the provision of key public services, fulfillment of constitutional mandates and public policy objectives, to understand how digitalization affect this workforce is deemed of highly strategic value for governments and citizens alike. The impact of automation technologies in the public sector workforce most likely would affect budgets, public services quality, and the institutional arrangements of European democratic regimes. Further pursuing this line of inquiry may inform policy makers and citizens on the policy options, best practices, human capital investments and legal amendments required to make better use of digital technologies in the public sector.

Future research should continue to explore the diverse ways in which digitalization impacts public sector workforces, focusing on factors such as organizational structures, job tasks, skill

requirements, and the nature of the technologies being implemented. By deepening our understanding of these complex dynamics, we can better inform policy and practice aimed at managing the opportunities and challenges presented by digitalization and automation technologies in various labor markets.

Another potential avenue for research is the exploration of cross-national differences in the polarization patterns observed in the public sector. Are there specific national contexts or institutional arrangements that make some countries more susceptible to workforce polarization because of digitalization? Understanding these variations could provide valuable insights into the development of targeted policy interventions aimed at minimizing the negative impacts of technological change on the public sector workforce.

In conclusion, while the adoption of digital technologies in the public sector has the potential to revolutionize service delivery and enhance operational efficiency, it is crucial for governments to navigate the complexities and challenges associated with this transformation. This includes investing in digital infrastructure, fostering a culture of innovation, and promoting digital literacy among public sector employees and citizens. By addressing these challenges and capitalizing on the opportunities presented by digital technologies, governments can work towards a more responsive, efficient, and inclusive public sector that effectively meets the needs of their communities.

By continuing to explore this complex relationship, researchers can develop a more nuanced understanding of the potential consequences and opportunities arising from technological advancements, ultimately contributing to more effective strategies for managing the future of work in both the private and public sectors.

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Appendix 2. Fixed-effects coefficients

	Fixed effects intercepts				
	(1)	**(3)**	**(4)**	**(5)**	**(7)**
Austria	9.771***	2.775	-5.286	0.189	-13.156**
	(3.181)	(3.427)	(4.184)	(4.016)	(4.246)
Belgium	12.207***	2.180	-5.258	0.546	-13.709**
	(3.164)	(3.409)	(4.162)	(3.995)	(4.224)
Czech Republic	7.294*	2.596	-4.640	1.528	-11.944**
	(2.983)	(3.215)	(3.925)	(1.527)	3.982
Estonia	7.191*	3.152	-5.718	2.349	-10.884**
	(2.962)	(3.192)	(3.897)	(3.740)	3.955
Finland	11.145***	4.105	-3.679	0.263	-11.467**
	(3.170)	(3.416)	(4.170)	(4.002)	(4.232)
France	10.890***	2.859	-5.304	0.547	-12.736**
	(3.146)	(3.390)	(4.139)	(3.973)	(4.201)

	Fixed effects intercepts				
	(1)	**(3)**	**(4)**	**(5)**	**(7)**
Greece	9.487**	0.028	-6.409	0.263	-13.673**
	3.034	(3.269)	(3.991)	(3.831)	(4.050)
Hungary	8.040**	2.936	-6.139	1.935	-11.035**
	(2.883)	(3.106)	(3.793)	(1.936)	(3.849)
Iceland	11.892***	4.596	-4.761	1.457	-12.489**
	(3.211)	(3.460)	(4.224)	(4.054)	(4.286)
Ireland	10.983**	3.380	-7.819	1.500	-15.300***
	(3.238)	(3.490)	(4.260)	(4.089)	(4.323)
Italy	7.980*	0.515	-7.694	0.828	-13.602**
	(3.176)	(3.422)	(4.178)	(4.010)	(4.240)
Latvia	7.449*	3.224	-4.978	2.993	-11.830**
	(2.903)	(3.128)	(3.819)	(3.665)	(3.875)
Lithuania	7.403*	2.794	-5.675	3.109	-11.677**
	(2.928)	(3.155)	(3.852)	(3.697)	(3.909)
Luxembourg	11.464**	2.388	-7.248	-0.381	-15.515***
	(3.420)	(3.685)	(4.499)	(4.317)	(4.565)
Poland	7.241*	2.522	-4.441	2.693	-12.550**
	(2.866)	(3.088)	(3.770)	(3.618)	(3.826)
Portugal	8.501**	2.646	-5.355	1.450	-12.694**
	(2.981)	(3.212)	(3.922)	(3.764)	(3.980)
Slovak Republic	8.083**	2.450	-4.693	2.544	-11.483**
	(2.964)	(3.194)	(3.900)	(3.742)	(3.957)
Spain	8.642**	1.236	-5.808	0.299	-13.043**
	(3.064)	(3.302)	(4.031)	(3.869)	(4.090)
Switzerland	10.171**	3.052	-5.294	-0.238	-13.237**
	(3.328)	(3.586)	(4.378)	(4.202)	(4.443)
United Kingdom	10.922***	3.078	-5.757	0.188	-12.568**
	(3.141)	(3.385)	(4.133)	(3.966)	(4.194)

Source: Table created in stargazer package for R programming language.

CHAPTER IV - DIGITALIZATION AND THE PUBLIC SECTOR WORKFORCE: UNBUNDLING THE ESTONIAN CASE

Abstract

Estonia has emerged as a regional leader on several e-government metrics, outperforming its European counterparts. In recent years, the digitalization of public services has been a common agenda across Europe; however, the rate of adoption and the maturity of these services exhibit significant variations at the national, regional, and local levels. This chapter delves into the Estonian case, seeking to understand the interconnections between digital transformation and the organization of work within the public sector. Estonia is considered an intrinsic case of study due to its performance in digital government indicators and the country's unique socio-political and economic trajectory in recent decades. Prior research has theorized potential impacts of digitalization on the public sector workforce, including staff reduction or substitution, work reorganization, and the evolving configuration of the public encounter - the interaction between citizens and businesses with public administration officials. This chapter employs a qualitative approach by interviewing nine (9) subject matter experts with verified experience in the Estonian e-government system as private contractors, government employees, and elected officials in combination with the analysis of secondary sources as a methodological approach to explore the effects of advanced digitalization in the Estonian public sector workforce. In addition, this chapter adopts an institutional stance by considering the complex and multifaceted political, economic, and social configurations evidenced in the Estonian case. The intricate institutional and technical multilayered building blocks of the case are unbundled and discussed to understand the set of technologies in conjunction with regulatory and cultural factors that have facilitated this country's level of digitalization. The Estonian configuration of public services has reached most features of a modern economy and society, including aspects such as tax collection, digitalized health services, and political participation via electronic voting. Digitalization has changed the way public services are rendered in Estonia, a complex array of institutional factors and very high adoption levels by the population has altered the traditional interaction among citizens, organizations, and the State. Also, it has transformed the functions and task content of front-line employees and other public sector workers and has led to the redesign of public sector front-office, back-office, and support

services into a digitally enabled shared service model. This transformation not only signifies a shift in the mode of service delivery but also signals a fundamental change in the working dynamics of the public sector workforce. Two salient and seemingly reinforcing conditions inform the relationship between digitalization adoption and the public sector workforce: on one hand, the country's historical labor and skill shortages, and on the other, the pursuit of austerity-driven, and technology-enabled redesign of public services.

Keywords: digitalization, Estonia, public sector workforce, institutional factors, expert interviews, single case study, organization of work

1. Introduction

Estonia is a very particular country. Once a Soviet republic and currently a member of the European Union, this Baltic republic regained its independence in the early 1990s and embarked on a distinct path of transformation. Today, it stands as a leader in the digitalization of public services, exhibiting a comprehensive array of digital infrastructure that undergirds the functionality of modern society and a progressively sophisticated economy, business environment, and innovation ecosystem. Research has found that the implementation of digital government tends to be more successful in smaller countries and sociopolitical factors such as institutions shape adoption of digital technologies (Glyptis et al., 2020; Stephany, 2020). In addition, Estonia has experienced fiscal constraints and has adopted recurrent fiscal discipline policies leading to austerity measures to balance the budget in different moments of its recent history, from the early days of its regained independence, joining the euro-zone, and the aftermath of the 2008 financial crisis (Raudla, 2010; Raudla & Kattel, 2011).

Since the 1990s this Baltic nation has embarked on a steady journey toward establishing a vibrant and resilient digital society, a reputation it now proudly bears. This transformation was not an overnight phenomenon but resulted from consistent iterations and incremental steps taken over decades toward digitalizing public service delivery. The institutional, technical, and societal evolution that has allowed the rapid adoption of digital technologies in Estonia is supported by regulation and political agreements, technical standards in terms of privacy and cybersecurity, and a high degree of trust and adoption and use by its population.

Estonia's integration into the international community has been signified by its membership in various global organizations. Joining the European Union and the North Atlantic Treaty Organization in 2004, the Organization for Economic Co-operation and Development in 2010, and the Eurozone in 2011 has broadened Estonia's global reach and significantly influenced its economic, political, and digital trajectories. Estonia's visionary political agreements regarding digitalization materialized in a foundational legal framework that has matured and adapted to accommodate the needs of a rapidly digitalizing society. This legal apparatus has provided the necessary scaffolding to facilitate the seamless integration of technology into the workings of the state and the economy, enabling the emergence of a robust digital infrastructure and technology ecosystem. Critical digital public infrastructure includes the digital identification of the population, transaction channels, and data exchange systems. Estonia is considered one of the most digital countries in Europe as it has recognized the right to internet access for its citizens as early as the year 2000, adopted electronic identification for its population, national and local elections are conducted via digital means, and hundreds of other public (and private) services are currently available and provided digitally.

In this chapter, we describe what we have observed to be building blocks of Estonian advanced digitalization. The unbundling of the case encapsulates the intricate interplay between regulatory, technological, cultural, and political elements that have collectively facilitated Estonia's remarkable digital transformation. The "regulatory" component refers to the robust legal frameworks and policies that have been implemented to support digital initiatives. The "technological" aspect pertains to the innovative infrastructure and digital solutions that have been developed and adopted across various sectors. The "cultural" element highlights the societal acceptance and enthusiasm towards digitalization, which has been instrumental in driving its widespread adoption. Lastly, the "political" building block underscores the role of government leadership and commitment in steering the nation towards a digital future. Together, these interconnected building blocks have propelled Estonia to the forefront of digitalization, setting a benchmark for other nations to aspire to.

The digitalization of public services is not homogeneous in Europe, there are several metrics and indices to evaluate the performance of European countries through diverse digitalization indicators (Yera et al., 2020). Estonia ranks first in the digital public services indicator from the 2022 Digital Economy and Society Index (DESI), but is a laggard in comparison

with other European countries in terms of connectivity (European Commission, 2022), in addition, Estonia boasts first place in the Online Service Index, a sub-component in the United Nations' E-Government Survey (United Nations, 2022).

As eloquently put by a group of scholars:

> *Famous for its e-government developments, particularly the electronic ID card and secure data exchange architecture (so-called X-Road) underlying it, Estonia has successfully launched one of the leading solutions of its kind globally. Near universal diffusion of the electronic ID card among citizens has led to the fact that almost all personal income taxes are filed online, nearly all medical prescriptions are issued electronically, and other e-services cover a wide range of areas (central and local governments offer some 2500+ services fully on-line). […] Estonia is known for its exceptionally high social trust towards e-government solutions, where privacy-related issues have very little impact on policy debates and where ICT has become one of the building blocks of national branding. (Kattel et al., 2019, p. 10)*

In this chapter, we adopt a single case approach, drawing from the rich tapestry of institutional literature and the domain-specific contributions from work and organizational studies, where technology is understood as an 'embedded system' deeply entrenched in a specific 'time, place, discourse, and community' (Orlikowski & Iacono, 2001), in addition, the industrial relations literature also considers the effect of labor market institutions such as unions in the deployment of automation technologies (Haipeter, 2020; C. Lee & Kim, 2023). Technology availability and diffusion might seem globally homogeneous, but states and societies are not, creating different levels of adoption and maturity among diverse jurisdictions (Rose, 2005).

This chapter focuses on the last two decades of Estonia's digital evolution through an institutional lens by considering the technological, regulatory, and organizational developments that have enabled this country to provide a wide array of public services to its population via digital channels, thus changing the organization of work in the public sector workforce. Our goal is to understand how the digital transformation of public services has reshaped the roles, skills, and interactions within the public sector and how it continues to inform the evolution of public service delivery in this leading e-government nation.

The selection of the time interval for this analysis is not arbitrary but deliberately informed by two key criteria: one technological and one institutional. The technological criterion is rooted in the widespread diffusion of digital technologies, a phenomenon that some scholars argue began in earnest in the late 2000s with the advent of 'digitalization as a new normal' (Ritter & Pedersen, 2020). This period also witnessed the emergence and evolution of the Digital Platform Economy, facilitated by the cumulative diffusion and adoption of transformative technologies such as broadband internet, mobile devices, and social media.

Noteworthy within this technological landscape is the advent of cloud computing over the past decade. Cloud-based services 'have revolutionized how business is conducted today' (Acs et al., 2021). This revolutionary impact extends beyond the realm of the private sector and became part of the key operational infrastructure of the public sector as well. The transition from paper-based systems to cloud-based solutions has introduced substantial changes in the design, provision, and staffing of public services (J. Lee & Reed, 2018). This technological shift has not only streamlined service delivery but also engendered transformative changes in the roles, skills, and interactions within the public sector workforce. Estonia has introduced legislation to enable to digital-by-default, digital-by-design, or digital-first principle.

The institutional criteria derive from implementing the Civil Service Act of 2013, the prevailing legislation governing Estonia's public sector workforce. This reform underscores the country's unique labor market dynamics. The reform established two distinct categories within the Estonian civil service: officials (or civil servants) and employees. Officials are governed by specific civil service regulations, the latter are subject to general labor law. This dual structure, combined with the low unionization rate and the regulation of public employees' contracts by general labor law, offers valuable insights into the deeply embedded nature of Estonia's digitalization process and its impact on the organization of work in the public sector.

The Civil Services Act heralded the incorporation of managerial practices styled after the private sector, originating from the New Public Management (NPM) tradition, into Estonian public administration (Randma-Liiv & Drechsler, 2017; Pesti & Randma-Liiv, 2018; Randma-Liiv et al., 2022). The adoption of ICT has played a pivotal role in propagating NPM practices (Cepparulo & Zanfei, 2021), including the inception of shared service center (SSC) models within a public sector context (Janssen & Joha, 2006; Tomasino et al., 2017). Shared service centers strive to standardize

and consolidate, aiming to curtail costs and headcount associated with non-core or back-office functions of the public sector by amalgamating them into a singular service provider (Tammel, 2017).

On the institutional criterion, the past couple of decades has also been a period of significant institutional developments and regulatory shifts in the Estonian public sector, which have shaped and influenced the diffusion, adoption, and impacts of these digital technologies. Thus, the selected time interval offers a rich and critical period for understanding the interplay between digitalization and the public sector workforce, providing valuable insights into the transformative potential of digital technologies within institutional contexts.

The digitalization of public services is mostly studied in the multidisciplinary domain known as Digital Government and it is experiencing a growing interest in academic, practitioner, and policy circles. Despite the current momentum in digital government research, one aspect that, to the best of our knowledge still is underexplored, is the effects of digitalization on the public sector workforce (Plesner et al., 2018).

There is a considerable body of research exploring the impact of diverse automation technologies, including digital technologies on the organization of work, much of this analysis has been conducted within the context of the private sector (Filippi et al., 2023). Paradoxically, the public sector in general is a substantial adopter of information and communication technologies (ICT) and has often been overlooked despite its massive, diverse, and highly educated workforce. The public sector's adoption of digital technologies and its implications for work organization merit significant attention. The pervasive use of ICT in this arena not only shapes how public services are delivered but also transforms how public sector employees perform their roles and interact with each other, with citizens, and with other stakeholders.

The extensive deployment of digital services, platforms, and critical digital infrastructures is not confined to the sphere of private corporations but has permeated public organizations as well, reshaping the landscape of work in profound ways (Nambisan et al., 2019). The effects of these technological developments are multifaceted, influencing not just the nature of tasks and workflows but also the broader organizational structures, cultures, and institutional practices within the public sector and society at large. Considering these ongoing transformations, it

becomes increasingly critical to investigate the dynamics of digital technology adoption in the public sector and its implications for work organizations.

In this context, we formulate the following research questions for this chapter:

RQ1: How has the institutional configuration (both formal and informal) contributed to the advanced stage of digital government in Estonia?

RQ2: How did behavioral incentives and nudges affect the level of adoption of digital services in Estonia?

RQ3: How did the digitalization of public services and the unique institutional factors found in Estonia change the country's public sector workforce over the years?

To address them, an interview protocol was devised considering the relevant theoretical framework regarding institutional drivers and barriers to digital transformation, what behavioral interventions or incentives contributed to the adoption of digital services, and how these configurations may have altered the organization of work in the public sector. The pursuit of such an analysis would enrich our understanding of the intricate interplay between technology, work, and institutional factors in a public sector context, thereby contributing valuable insights to the broader discourse on digitalization and work in a non-market environment.

This chapter is organized into five sections, including the foregoing introduction. The second section reviews relevant literature delving into the subject matter of this manuscript. The third section describes the research strategy and methods used in this chapter. The fourth comments on the findings of this inquiry and the fifth and last section provides some comments and suggests potential research avenues on this topic.

2. Literature review

Estonia has emerged as a global leader in digital government development, setting a benchmark for other countries to follow. Since regaining its independence Estonia has embarked on a digital transformation journey that has revolutionized its public sector, making it one of the most digitally advanced nations in the world (Feldmann, 2013). The country's digital government strategy is centered around the principles of efficiency, transparency, and accessibility, which have created a seamless and user-friendly digital environment for its citizens (Kalvet, 2012). Thus

making Estonia a success story in digital transformation of its public services, economy and society at large (Kattel & Mergel, 2019). The Estonian government claims that 99% of its services are available online, with few exceptions such as getting married and buying or selling property.

This chapter aims to explore the institutional factors of the digitalization process in Estonia and its effects on the public sector workforce. The pervasive digitalization process of modern society is allowing a more specific division of labor into the smallest possible tasks (Cherry, 2015), opening more opportunities for the implementation of self-service solutions thus changing the public encounter between citizens and public officials into an 'encounter of the digital kind' (Lindgren et al., 2019; Madsen et al., 2021) and facilitating scenarios for the co-production of public services (Scupola & Mergel, 2021) and turning each citizen into "*his or hers own administrator, caseworker and bureaucrat*" (Schou & Hjelholt, 2018).

Studies on the effects of technology on public sector jobs have emphasized the importance of country effects or the role of institutional settings and national social actors in the implementation of technologies for the public sector (Lloyd & Payne, 2019). Context and institutional arrangements affect policy outcomes, this analytical line is also found in the varieties of capitalism literature (Hall & Soskice, 2001), varieties of welfare (Hicks & Kenworthy, 2003), varieties of the regulation (Schröder & Voelzkow, 2016), varieties of citizen and user participation in public services (Nabatchi et al., 2017), and varieties of legacies, for the case of the public administration reform in East and Central Europe (Meyer-Sahling, 2009) and more recently in varieties of digital capitalism and the role of states in internet governance (Chenou, 2021).

Another institutional perspective that merits attention is derived from the National Innovation System (NIS) literature. This body of literature places significant emphasis on the institutional configuration as a key determinant that shapes the process of innovation at a national level. Within this framework, the public sector plays a prominent role, serving as the orchestrator that coordinates the interactions among the various actors in the system (Freeman, 2004; Lundvall, 2004).

The NIS approach underscores the importance of the systemic interplay between institutions, policies, and actors in fostering a conducive environment for innovation. It posits that the way these elements are orchestrated can significantly influence the pace and direction of innovation within a country. In this regard, the public sector emerges not merely as a passive

player, but as a facilitator, provider of critical digital infrastructure (i.e., electronic identification services, eID), and regulator of the innovation ecosystem. Consequently, the NIS perspective provides a comprehensive lens through which we can examine the role of the public sector in the digitalization process. It allows us to understand how the institutional environment and public sector actions can shape the adoption and impact of digital technologies, thereby influencing the transformation of the public sector workforce. This approach is particularly relevant in the context of Estonia, where public sector-led digitalization has been a critical component of the nation's innovation strategy.

Both the Varieties of Capitalism (VoC) and the National Innovation Systems (NIS) approaches emphasize the significance of differing institutional contexts as pivotal factors in determining the outcomes of policy implementations. These institutional approaches, grounded in comparative political economy and innovation studies respectively, underscore the nuanced ways in which distinct institutional architectures can shape the effects of policy interventions. As such, it is postulated that the impacts of technological change, and more specifically digitalization, are not uniform across different countries or sectors. This heterogeneity can be attributed to the variation in institutional configurations, policy landscapes, and socio-economic conditions that characterize different nations (Lloyd & Payne, 2021; Milner, 2006).

In other words, the effects of digitalization are mediated by the prevailing institutional contexts within which they are implemented. This perspective challenges the notion of a 'one-size-fits-all' model of digital transformation, highlighting instead the importance of understanding and accommodating the distinct institutional factors that can influence the course and outcomes of innovation and digitalization. This understanding is crucial in informing the design of digitalization strategies and policies, ensuring that they are tailored to the specific institutional contexts and needs of different countries and industries (Zanfei, 1993). In the case of the public sector, it highlights the need for a nuanced understanding of how institutional factors can shape the adoption and impact of digital technologies, thereby influencing the transformation of the public sector workforce.

Institutional approaches in the field of digital government have helped to conceptualize the interaction of technology in organizational structure and organizational change (Fountain, 2001). The Technology Enactment Framework has been used to comprehend how information

technologies affect organizational structure and organizational change. From the Information Science perspective, the Technology-Organization-Environment (TOE) Framework considers the interaction of these diverse aspects in the implementation of innovations in organizations (Baker, 2012), including relatively recent approaches have considered the role of leadership in shaping the innovation capacity in the public sector (Lewis et al., 2017). In this chapter, we feature the importance of the Estonian institutional context in which digital government is enacted, implemented, and adopted and the reported effects on the public sector workforce.

Digitalization of public services is considered complex endeavor, adoption and maturity models have been devised and adapted through the years to inform the diverse phases and levels of performance, early maturity models preceded technological developments like the rise of social media or the ample diffusion of mobile devices. The classic model (Layne & Lee, 2001) describes four stages of e-government maturity (information sharing, transaction, vertical integration, and horizontal integration) considering complexity and integration focusing mostly on a technical standpoint, the maturity model by (Andersen & Henriksen, 2006) built on Layne and Lee's model and included issues as customer, citizen and user centricity as an additional dimension of analysis.

A collection of maturity models can be found in (Almuftah et al., 2016; Iannacci et al., 2019), in these works the authors provide a quick overview of the diverse maturity models found in the literature. Two of these models considered e-democracy or the possibility of citizens' political participation using digital means, i.e. electronic voting or online consultations, as the most advanced stage of digital government maturity (Moon, 2002; Siau & Long, 2005). By these models, Estonia is a true pioneer and leader in the development of electronic forms of political participation e-democracy, and internet voting, since 2005, Estonia has conducted several elections in electronic form (Ehin et al., 2022).

The creation of proactive services is also considered in recent maturity models as an advanced stage of digital government (Scholta et al., 2019), due to the availability of vast amounts of citizens' data, the integration and interoperability of governments' services in combination with advanced tools for data analysis such as artificial intelligence and machine learning, have allowed the Estonian government to anticipate citizens' needs due to the mapping of life events of the population (Maksimova et al., 2021).

Due to technological and institutional developments, including increased deployment and adoption, digital innovations, and automation technologies, such as ICT, Artificial Intelligence (AI), blockchain, big data, and Internet of Things (IoT) devices among others, are becoming objects of research interest as a subset of the public sector innovation literature. It has been theorized that digital innovations in the public sector arena respond to four determinants: 1) citizens' demand, 2) electoral incentives, 3) isomorphic pressure and 4) the demographic profile of the leadership (Hong et al., 2022). All the above are embedded in a country's institutional configuration such as public trust in public digital services, regulatory framework, market structure, technological readiness among others.

The literature on public sector innovation has considered the push and pull factors in innovative activities (Clausen et al., 2020). However, most of the conceptualization of technology-push and demand-pull come from the analysis of organizations in the private sector (Di Stefano et al., 2012), supply and demand side are deemed equally important as success factors for the case of Italy (Arduini et al., 2010). The public sector operates under a different logic in non-markets or quasi markets, the need for democratic and public accountability may influence how push and pull factors operate for the digital provision of public services, thus the need of a public service logic (Osborne, 2017; Osborne et al., 2013). In addition, the complexity associated with the public sector, a more elaborate discussion is found in the design and use literature that incorporates analytical dimensions such as power, ideology, design and institutional change in the study of how novel technologies affect the organization of work (Bailey & Barley, 2020).

Sustained cross-party support in parliament for the digital agenda in Estonia may be evidence of electoral incentives and the commitment by the political leadership to the pursue of this policy due to the perceived convenience and modernity of providing public services electronically (Di Giulio & Vecchi, 2021). In addition, national milestones like the accession to the European Union and the proximity to leading countries in digitalization such as Finland and Denmark, may support the isomorphic pressure argument (Ernsdorff & Berbec, 2007), this is deemed of importance given that it has been reported that up to 85% of Estonian government spending on ICT has been financed through the European Union Structural Funds (Nielsen, 2017). Measured by diverse indicators, Estonia has improved clearly in digital government indicators and rankings over the years surpassing some of the largest economies in the European Union.

The timing of the regained independence of Estonia provided an important coincidence of events, Estonians had the opportunity to a clean slate to break with a Soviet past in the 1990s, co-occurring with the expansion in the diffusion of computer technology globally. Framed in terms of bottleneck analysis, the focusing device argument by (Rosenberg, 1969), we could argue that Estonia had a significant challenge in launching an independent yes, but fiscally constrained nation state likely pushing to find a solution in the relatively early digitalization of Estonian public services to be able to cope and do more with less. In addition, the country accession to the European Union has exacerbated historical labor and skills shortages (Eamets, 2016; Hazans & Philips, 2009), leading us to contemplate these two factors as momentous constraints for the policy choices leading to the widespread adoption and use of digital technologies, including the world famous Estonian e-Residency program to attract business and digital nomads to be digital residents of Estonia (Sullivan & Burger, 2017; Tammpuu & Masso, 2018). This is the case for a single case, digital technologies are embedded in a complex system in which time, place, discourse, and community may affect the organization of work and reconfiguration of tasks in a public sector context (Klein & Watson-Manheim, 2021).

Barriers to innovation in the public sector have been explored in the literature (Cinar et al., 2018; Gallouj & Zanfei, 2013; Savoldelli et al., 2014). Barriers to digital government can be categorized as structural, related to regulation, institutional and technological capacity, technological readiness and quality of the infrastructure; or as cultural barriers associated with norms, perceptions and expectations (Meijer, 2015). In Europe, a leading region in digital government adoption and usage, it may seem that structural barriers have been overcome.

> *After several decades of government technology adoption, this would suggest structural obstacles have in many cases been overcome, and contemporary digital government challenges will be more cultural than structural in nature. It may also be that processes of digital government are generally too complex and contingent as to discern any such consistent patterns.* (Wilson & Mergel, 2022, p. 3)

The cultural aspects to digital government adoption has been in the research agenda of the discipline, trust in government vary from jurisdiction to jurisdiction (Bannister & Connolly, 2011; Carter et al., 2016; Carter & Weerakkody, 2008; Fuglsang & Jagd, 2015). Several issues come to mind when discussing trust framed in digital government adoption, from political stances towards

government information systems to the technical aspects of information security. Politics and culture may shape the outcome of e-government initiatives by the role played by political elites, the role of administrative sectors and the legacy of the political culture. Making cultural barriers an important explanatory variable in the success or failure of digital government initiatives (Bolgherini, 2007).

Countries across Europe have adopted diverse strategies to encourage or nudge their citizens towards the utilization of digital government services (Giest, 2020). This diversity of approaches has sparked a rich discourse on behavioral interventions, service design, and the use of 'nudges'—subtle prompts that influence decision-making— as tools to alter levels of adoption and usage of digital services among different nations (Faulkner et al., 2019; Hyytinen et al., 2022). For instance, European nations with comparable political configurations have implemented their digital communications with citizens and businesses in starkly different manners, reflecting distinct strategic approaches and cultural nuances. Denmark has opted for a mandatory approach, compelling its citizens to use digital communication channels with the government. On the other hand, Sweden has embraced a voluntary approach, allowing its citizens to choose whether to utilize digital platforms for public communications. Meanwhile, Norway has charted a middle course, opting to nudge its citizens towards using digital platforms for public communication (Jansen et al., 2016). This strategy relies on subtly influencing citizen behavior through carefully designed interventions, rather than imposing outright mandates or leaving the decision entirely to individual discretion.

Estonia adopted a diversified approach to induce digital service diffusion. The Estonian government claims that 99% of its services are available online, usage data analysis at a population level demonstrate a strong adoption across most demographics, but particularly among females and the young (Solvak et al., 2019). However, these levels of adoption and usage are embedded in significant path dependencies unique to the Estonian case. For instance, the mandatory nature of electronic identity services (eID) since 2002 (Bharosa et al., 2020), the data exchange infrastructure, known as X-Road connecting the diverse databases with specific public (and private) services (Lips et al., 2022), and service design principles such as the “Once-Only Principle” in which the Estonian law prohibits the creation of separate databases for the same data (Krimmer et al., 2021).

These contrasting strategies illuminate the nuanced ways in which different countries navigate the complex task of digital transformation. They also underscore the importance of carefully considering the cultural, social, and political contexts in which these digital initiatives are implemented. Understanding these contextual factors can help shape more effective digitalization strategies tailored to different populations' specific needs, capabilities, and preferences.

Thus, public administrations are confronted with the conundrum of offering public services through both traditional and digital channels. This multichannel strategy for service provision presents a complex challenge. While it may increase accessibility and cater to diverse preferences, it could also potentially lead to escalated costs if the usage of traditional channels persists at high levels. Furthermore, certain demographic groups or specific client profiles might demonstrate resistance to digital adoption, further complicating the transition towards digital service delivery.

Mandating the provision of digital services might initially appear as a solution to drive digital adoption, but such a strategy could inadvertently foster undemocratic outcomes. It may risk excluding vulnerable segments of the population who are unable to engage with digital services due to various barriers. These barriers could stem from a range of factors including age, immigration status, limited access to necessary infrastructure, or insufficient digital skills to engage effectively with the public sector through digital channels. For instance, elderly individuals may face challenges in navigating digital platforms, while immigrants might grapple with language barriers that impede their ability to use digital services (Schou & Pors, 2019; Tangi et al., 2021). These considerations highlight the need for a balanced and inclusive approach to digital transformation in the public sector. It underscores the importance of ensuring that the shift towards digital service delivery does not exacerbate social inequalities or marginalize certain groups but facilitates broader, more equitable access to public services.

Design principles for public services such as 'digital by default' or 'digital first' can initially appear to offer the allure of convenience, efficiency, and modernity. However, when not carefully implemented, these principles risk excluding less informed or disadvantaged segments of the population. This potential exclusionary effect could undermine democratic values and create undue administrative burdens for users and citizens (Larsson, 2021; Madsen et al., 2021; Reissig et al., 2022).

Behavioral interventions represent one set of tools that governments can employ to incentivize the use of digital channels for service provision (John & Blume, 2017). By leveraging insights from behavioral science, governments can design interventions that enhance the convenience, ease of use, and perceived benefits of digital services. These interventions can draw on a range of behavioral concepts that have been identified in the literature as effective in increasing the usage of e-government solutions by citizens and businesses (Faulkner et al., 2019).

The role of the private sector in the development of digital public services is undeniably significant. The interplay, collaboration, and synergy between the public and private sectors have been instrumental in driving digital innovations in the public sector, fostering the creation and enhancement of digital services that cater to the evolving needs of citizens, the literature has duly recognized this interaction and the mutually beneficial relationship between the two sectors. In this context, the private sector emerges as a pivotal partner and ally in the government deployment of digital services. It contributes not only through providing resources and expertise but also through fostering innovative approaches and technological solutions that can enhance the effectiveness and reach of public services.

One prominent manifestation of this public-private partnership is Information Technology (IT) outsourcing, where governments enlist the services of private entities to manage and execute their IT functions (Duhamel et al., 2014). This model allows governments to leverage the private sector's technical expertise, operational efficiencies, and innovative capacities while focusing their resources on core governance functions.

In the process of digitalizing public services, public administrations frequently establish partnerships with a wide range of entities from the private sector. These partnerships extend across the spectrum of technology service providers, encompassing entities offering consulting services, telecommunications infrastructure, cloud services, and more. Beyond these traditional partnerships, collaborations also extend to non-governmental organizations (NGOs), citizen groups, and other private organizations in an effort to create public value and ensure that services are responsive to the diverse needs of the community (Picazo-Vela et al., 2018).

In the context of Estonia, the critical role of the private sector in developing and implementing digital public services is particularly noteworthy. The dynamic interplay between the public sector and private entities – encompassing banks, telecommunication companies, and

technology providers – has been instrumental in driving the country's digital government success (Kalvet, 2012; Kitsing, 2011). This case underscores the value of strong public-private partnerships in driving digital transformation in the public sector. It illustrates how such collaborations can accelerate the development and deployment of innovative digital solutions, enhance the accessibility and quality of public services, and ultimately contribute to the creation of a vibrant digital society.

A recurring theme in the literature has been the analysis of the impacts of ICT use and adoption and electronic government programs in public sector organizations. Since its introduction in the 1990s, Public Value Theory (PVT) has had a theoretical and conceptual evolution that has been deemed a more fruitful channel to explore the *complex socio-political impacts*, including the reorganization of work, redesign of service provision and quantity and quality of staff needed to provide services, related to the adoption of ICT the public sector (Cordella & Bonina, 2012; Panagiotopoulos et al., 2019).

Digital technologies have been perceived as facilitating the automation of routine (Bellamy, 2002) and some non-routine tasks (Bannister & Connolly, 2020), changing how public organizations aim to achieve their mission and mandates. Nonetheless, it was the covid-19 pandemic that can be considered the critical test on the potential and practical effects of digitalization on the working conditions of vast amounts of public sector workers in diverse jurisdictions (Kersing et al., 2022; Reina et al., 2022).

A systematic literature review on the empirical research regarding the impacts of e-Government provided a taxonomy of these impacts (MacLean & Titah, 2021). In their findings, the authors reported that investments in e-Government can generate public value for taxpayers and citizens, it can improve the productivity of clients of public services and governments, and lead to transformation in the relationship between government and citizens. Thus, the “new” public encounter takes places via digital means pushing for changes in staffing decisions, including work and service redesign (Andersson et al., 2021). As argued by (Lember et al., 2018), technology, including digitalization, changes the role of bureaucracy and work organization in many ways.

3. Research design and methods

The research design and strategy adopted for this chapter is underpinned using a single case study methodology, a robust and widely recognized approach for in-depth exploration of complex phenomena within their real-life context (Eisenhardt & Graebner, 2007; Yin, 2018). The focus of this case study is Estonia, intending to elucidate the relationship between the digitalization of public services and the impact on the public sector workforce at a national level.

Our choice to employ a single case study approach is rooted in the argument that institutional factors, regulatory practices, and national path dependencies exert a significant influence on the outcomes of digital government policies. Thus, a detailed exploration of a single context, Estonia in this case, offers the opportunity to delve deeply into these influences and understand their interplay in shaping the digital transformation journey.

Intrinsic case studies, such as this one, are characterized by their exploratory nature. The primary objective of such studies is not to extend existing theory or to seek generalizable or transferable findings, but rather to examine a unique case for the richness and depth of insights it can offer. The specific idiosyncrasies of the case become the focus of the investigation, providing a richly textured understanding of the phenomena under study (Mills et al., 2010). In this respect, the Estonian case presents a compelling narrative on the effects of digitalization on the public sector workforce, set against the backdrop of its unique socio-political and economic context.

Estonia serves as a compelling intrinsic case for analyzing the ramifications of digitalization on the public sector workforce at a nationally aggregated level. Its recent political history, coupled with the swift and, by many measures, successful execution of a sophisticated 'virtual state' makes it an ideal case for this exploration. Intrinsic case studies may not be commonplace, but they hold considerable appeal due to the specific and unusual characteristics of the selected case (Scupola & Mergel, 2021). These studies offer valuable insights into the complexities and distinctions of specific contexts, contributing to a deeper, more nuanced understanding of how broader trends and phenomena play out in these unique settings. Thus, the Estonian case offers a distinctive perspective from a highly digitalized society and the effects of digitalization in the public sector workforce.

3.1. Data collection

The research for this chapter draws on both primary and secondary data sources. The primary data was collected through an interview process designed to capture the complexities and nuances of Estonia's digital transformation journey. Nine semi-structured interviews were conducted, each following an interview protocol that was specifically developed for this study. Data saturation was deemed achieved with few participants. Small N interviews, between 9 and 17 are reported to be enough to reach thematic saturation (Guest et al., 2020; Hennink & Kaiser, 2022). The protocol comprised seven open-ended questions, promoting a dialogue that allowed for comprehensive and in-depth responses.

Table 10. Research Questions and Interview Questions Alignment Table

Research Question	Interview Protocol Question
RQ1: How has the institutional configuration (both formal and informal) contributed to the advanced stage of digital government in Estonia?	What formal institutional factors have facilitated the incremental digitalization of public services in Estonia?
	What informal institutional factors have facilitated the adoption and diffusion of digital public services in Estonia?
	What has been the role of private sector workers (as contractors or as outsourced work) in the digitalization of public services?
RQ2: How did behavioral incentives and nudges affect the level of adoption of digital services in Estonia?	What type of behavioral interventions, incentives or "nudges" have been applied by the Estonian government to accelerate the adoption of digital services by citizens and firms?
RQ3: How did the digitalization of public services and the unique institutional factors found in Estonia change the country's public sector workforce over the years?	How has the digitally enabled co-production of public services changed the organization of work in the public sector?
	What functional group of the Estonian public sector has experienced the most significant changes in its workforce due to digitalization?
	How has the digitalization of public services changed the skills demand for public sector employees?

The questions within the interview protocol were crafted to explore various facets of Estonia's digitalization process from the existing literature related to digital government adoption and usage framed for the Estonian case. The protocol aimed for an open-ended style so the participants can contribute their expert knowledge to the subject matter of inquiry. In addition, the protocol was aimed to understand the unique institutional factors that have shaped the digitalization trajectory of Estonia, and to identify the strategies employed by the government to incentivize citizens to utilize online public services—a process often referred to as 'nudging'.

Next, the protocol addressed the role of the private sector in accelerating the digitalization process, acknowledging the potential of digital technologies to revolutionize the organization of work in public sector institutions, the interview questions also delved into the changes observed in the working methods and routines within these organizations. Finally, the protocol aimed to gain an overview of the kinds of jobs and occupations that have been particularly susceptible to digital transformation, marking areas of high impact within the public sector workforce.

The protocol consisted of seven questions, covering five major themes:

Part 1: General questions on the interviewees' background, expertise, and role in the digitalization of Estonian public sector.

Part 2: Questions about the formal and informal institutional factors and behavioral interventions and incentives that may have shaped the digitalization of government services in Estonia.

Part 3: Question on the role played by private sector workers in the digitalization process.

Part 4: Question on the issue of co-production in digital public services.

Part 5: Questions on the impact of digitalization on the public sector workforce skills and job demand.

The applied questionnaire can be found in Appendix 3.

Table 11. Interviewees Position and Present or Past Role Description

INTERVIEWEE	POSITION	ROLE DESCRIPTION
Interviewee 1	Senior Manager	Technical / Policy
Interviewee 2	Senior Expert	Advisory / Legal Analysis
Interviewee 3	Organization Director	Advisory

INTERVIEWEE	POSITION	ROLE DESCRIPTION
Interviewee 4	Senior Manager	Technical / Policy
Interviewee 5	Senior Manager	Legal / Advisory
Interviewee 6	Senior Government Official	Policy / Advisory
Interviewee 7	Senior Manager	Managerial
Interviewee 8	Senior Manager	Advisory / Policy
Interviewee 9	Senior Government Official	Policy / Advisory

Source: Biographical Responses to Interview Protocol

The interviewees included experts possessing substantial hands-on experience and practical knowledge in the digital government domain, academics renowned for their contributions to this field, consultants with extensive technical proficiency, and past and current high-ranking government and state officials. Each of these individuals has played a pivotal role in shaping and implementing Estonia's digital policies, making them invaluable sources of information for this study.

Although the number of interviewees, at nine, might seem modest, the depth and breadth of their expertise substantially compensates for this numerical limitation. The respondents collectively offered rich, diverse, and nuanced perspectives on the subject matter, thereby ensuring the comprehensiveness of the study. The individuals who participated in this study were identified as 'experts' based on the definition found in the literature. An expert, is a person who holds "technical, process, and interpretative knowledge" and possesses "relevant factual knowledge, aggregated or specific knowledge about processes, group behaviors, [and] strategic decisions" (Mergel et al., 2019). Each of the participants met these criteria, making their contributions integral to the understanding of the Estonian digitalization process and its impact on the public sector workforce.

The process of selecting experts for this study was achieved by a combination of convenience and snowball sampling methods. Convenience sampling, a non-probabilistic technique, allowed for the identification of experts based on their eminent national stature, as well as their current or past roles instrumental to Estonia's digitalization journey (Clark, 2017). However, in instances where experts identified via convenience sampling declined the interview invitation, the snowball sampling technique was employed. Snowball sampling allowed for the process to continue by asking the declining expert to recommend another authority in the field

(Rowley, 2012). This approach, akin to a chain referral, ensured that the pool of knowledge was replenished, and the data collection process was not hindered (Biernacki & Waldorf, 1981).

The interviews were conducted virtually from March to June 2022 using Microsoft Teams for videoconferencing, audio and video recording, and automated transcription. For decades, face-to-face interviews have been the predominant mechanism and "gold standard" to conduct interviews in social science (McCoyd & Kerson, 2006; Rowley, 2012), early accounts for alternative media to conduct interviews are found in the literature (Hanna, 2012), however with the evolution of digital technologies videoconferencing had become a more convenient solution for both researchers and participants (Archibald et al., 2019). Nonetheless, it was the covid-19 pandemic and restrictions to human mobility that marked a clear transition towards this "new normal" for this kind of data collection (Oliffe et al., 2021).

The interviewees were asked consent (either in written form or verbally, before the interview started) to be recorded in audio and video form with the assurance from the researcher to the anonymity of the participants and strict academic use of the data collected. The interviews were conducted in English, even though this was neither the interviewer's nor interviewee's native language. Despite the notable advances in automated transcription technologies, mistakes were found in the automated transcripts, minor adjustments were introduced to the transcript output to achieve a "naturalized" version, this is also known as "intelligent verbatim" in which the text adapts the oral to written norms, as opposed to "full verbatim" where every utterance, grammatical errors remain in the transcript (McMullin, 2021). The interviews had an average duration of 69 minutes.

The research process for this study was enriched by a six-month immersion in the city of Tallinn, Estonia, during this period, the researcher had the opportunity to interact with a broad range of individuals experiencing the Estonian digital landscape. Among these individuals were scholars specializing in digital government, Ph.D. students conducting research in the field, citizens who are the end users of these digital innovations, and expats who bring a global perspective to Estonia's digitalization journey. It is important to note that while these interactions provided a richer understanding of the context and cultural nuances, the primary data that forms the basis of this chapter is derived solely from the formal interview process.

Supplementary to the primary data gathered through expert interviews, the research design incorporated the use of secondary data sources to enrich the analysis and to ensure a comprehensive understanding of the digitalization process in Estonia's public sector. This secondary data, drawn from a range of reliable and authoritative sources, substantiated the information received from the interviews and offered additional perspectives that were instrumental to the research.

A fundamental resource in the field of Digital Government Scholarship is the United Nations E-Government Development Index (UN EGDI). The EGDI is a composite measure that encapsulates the progress of e-government development at the national level. It comprises three sub-indices that are weighted equally: The Online Service Index (OSI), which gauges the quality, robustness, and accessibility of online services provided by a government. The Telecommunication Infrastructure Index (TII) assesses the underlying technological framework that supports the functioning of e-government services. The Human Capital Index (HCI) measures the knowledge, education, and skills necessary for citizens to effectively use e-government services.

Secondary data were gathered from Estonian government websites, which provided up-to-date official information about the state's digitalization regulations, initiatives, strategies, and achievements. Data from United Nations, Eurostat, and others offered valuable insights into the country's demographic, economic, and technological landscape, crucial to understanding the societal context within which digitalization is taking place.

Archival documents and legislation served as an essential source of historical data, enabling a review of the evolution of digitalization policies, and the changes in the public sector workforce over time. International databases, such as OECDstat and the International Labor Organization, offered comparative data, allowing Estonia's digital journey to be contextualized within a broader, global framework.

These secondary sources played a significant role in the triangulation of data, enabling the cross-verification of interview statements and ensuring the credibility and validity of the research findings. This multi-pronged approach to data collection, combining primary and secondary data, contributed to a robust, holistic, and nuanced understanding of the impact of digitalization on Estonia's public sector workforce.

3.2. Data analysis

Interview data is unstructured audio, video and text data that requires certain treatment to make it useful for researchers. The intelligent verbatim transcripts for the data collected account for roughly 10.5 hours of audio and video recordings, the transcription documents contain more than 123,000 words in almost 16,000 sentences. For this dataset we used MAXQDA 2022 Analytics Pro Computer-Assisted Qualitative Data Analysis Software (CAQDAS) to help store, code, annotate text, retrieve, visualize data, and perform varied types of analysis like code sequence analysis, codes frequency, cluster among others. Qualitative Data Analysis software has been in the toolbox of researchers and offer a practical solution to process unstructured data (Rowley, 2012).

The data analysis process followed a deductive thematic analysis, which builds from prior research and existing theory to guide the analysis of the impact of the digitalization of Estonian public services on the public sector workforce.

> *[…] thematic analysis is a qualitative research method that can be widely used across a range of epistemologies and research questions. It is a method for identifying, analyzing, organizing, describing, and reporting themes found within a data set […] described thematic analysis as a translator for those speaking the languages of qualitative and quantitative analysis, enabling researchers who use different research methods to communicate with each other.* (Nowell et al., 2017, p. 2)

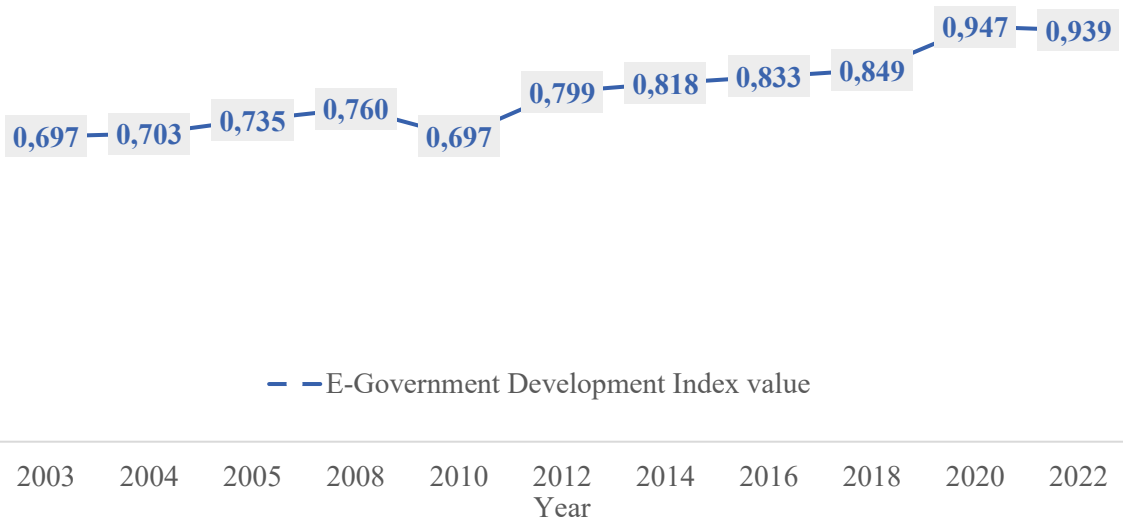
This type of analysis is interpretative, shaped, and informed by conceptual frameworks and theory that helped to formulate our research questions. The aim was to identify the unique institutional configuration of the Estonian process of digitalization of public services, the role of the private sector on this and the potential changes to the Estonian public sector workforce. A hybrid coding strategy was carried out by applying structural coding and in vivo coding to identify the main patterns behind the digitalization of Estonian public services and its influence over public sector jobs (Saldaña, 2016).

The combination of primary and secondary data sources provided a rich tapestry of information, enabling a detailed exploration of the multifaceted impact of digitalization on Estonia's public sector workforce. The first source evaluated is the E-Government Development

Index. The EGDI provides comprehensive and comparative data for a country's digital governance capabilities and progress over time.

In the case of Estonia, the values of this index have consistently risen over the past decade. This sustained growth is indicative of Estonia's persistent commitment to digital government development and positions this small Baltic Republic as a global forerunner in the realm of digital governance. The continuous improvement in the EGDI scores underscores Estonia's relentless pursuit of digital innovation, demonstrating its leadership role in the digitization of public services at a global scale.

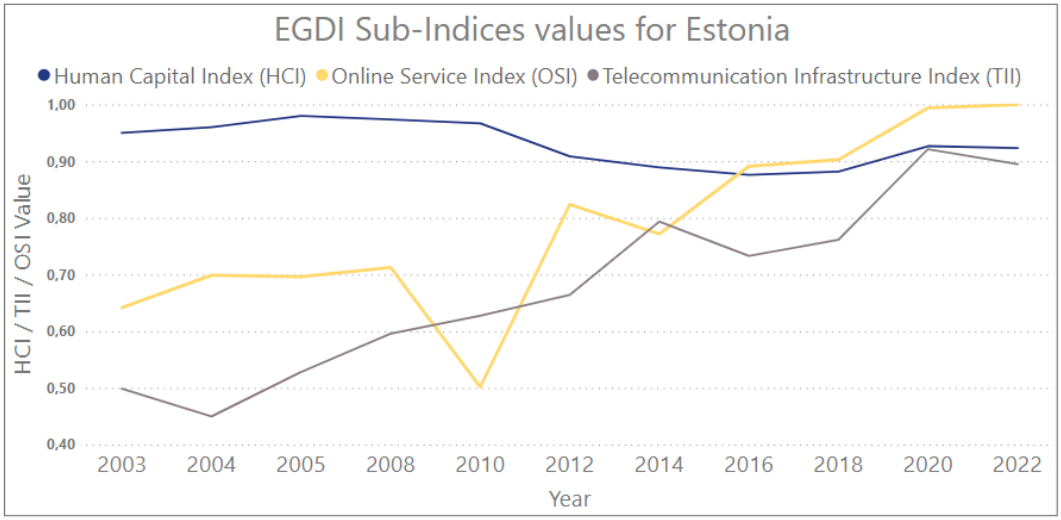
Figure 9. Historical United Nations EGDI values for Estonia



Source: United Nations, E-Government Development Index 2022

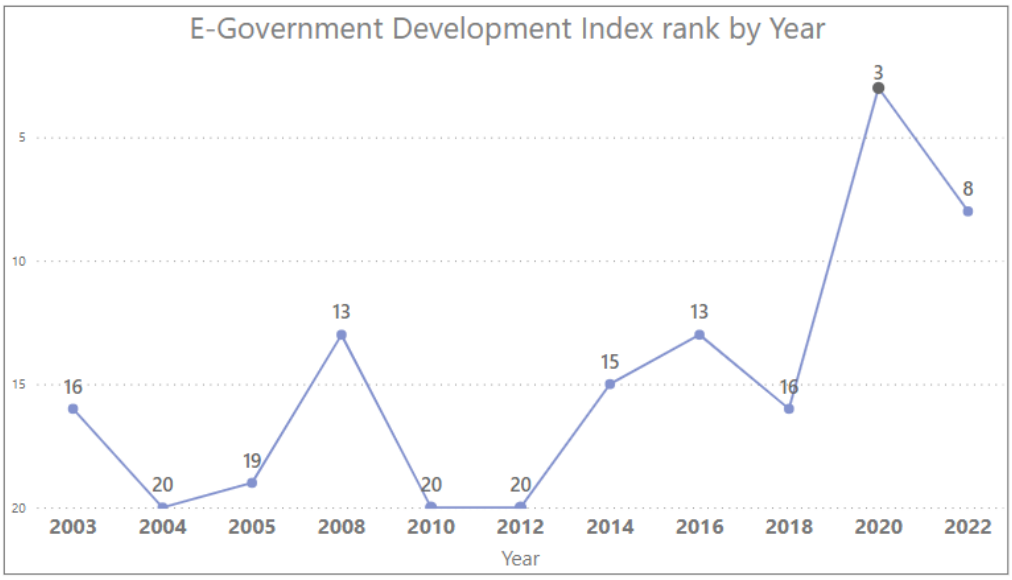
While the raw values of the United Nations E-Government Development Index (EGDI) depicted in Figure 9 and the values of three different sub-indices in Figure 10 provide insight into Estonia's e-governance growth, an even more compelling perspective is gained when we examine Estonia's global ranking derived from this index. This perspective not only contextualizes Estonia's progress, but also places it in comparison to other countries globally.

Figure 10. EGDI Sub-indices Estonia



Source: United Nations, E-Government Development Index 2022

Figure 11. Estonia's Rank in the United Nations EGDI



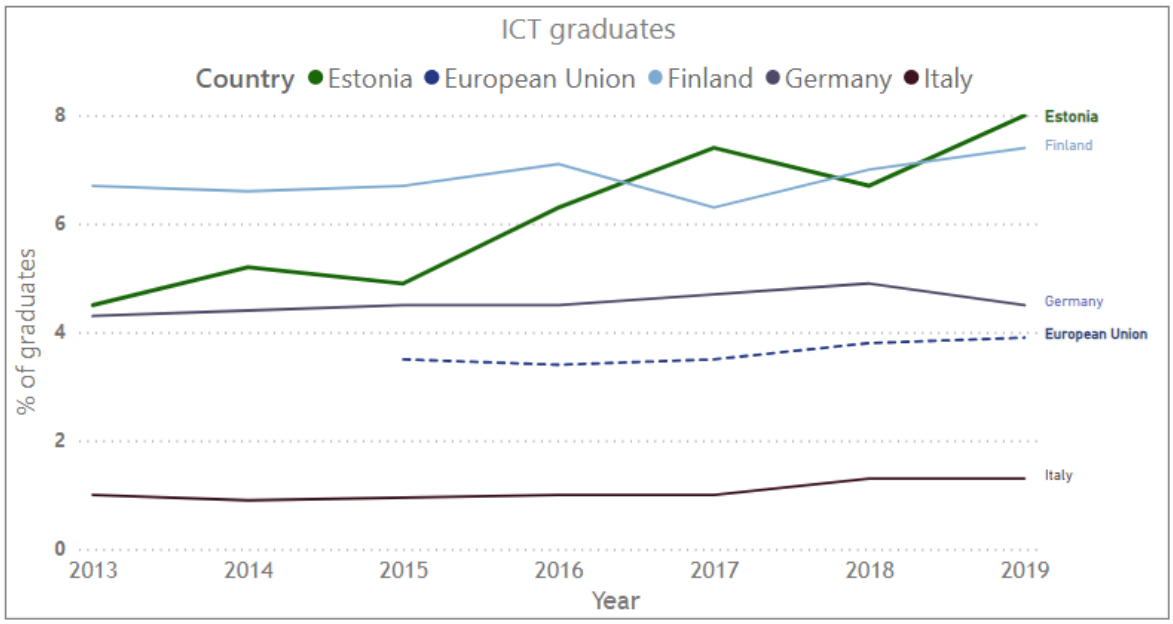
Source: United Nations, E-Government Development Index 2022.

Figure 11 depicts the trajectory of Estonia's performance in the realm of digital government on a global scale compared with 190 plus nation states and territories. It presents a vivid illustration of the country's evolution of its global rank over time. It started promisingly at Rank 16 in 2003, up to 13 in 2008. The most dramatic evolution in this country's performance is from 2012 to 2020.

This year, 2020 Estonia positioned itself at the Top 3 in Digital Government according to these metrics. This chart encapsulates the story of Estonia's journey from a small Baltic state to a global powerhouse in digital governance. It traces the incremental yet steady rise of Estonia to the upper echelons of digital government deployment worldwide.

The theoretical framework described above hinted us to think about the complex and intertwined institutional configuration of Estonia in terms of the diverse building blocks of regulation, technology, culture, and policy. The Estonian institutional evolution towards digitalization started earlier than other European countries, Estonia implemented mandatory digital identification for its citizens, enacted laws regulating government data management, citizens privacy, and cybersecurity. For years promoted adoption and diffusion of ICT and digital literacy through programs like Tiger Leap for schools (Runnel et al., 2009). As seen in Figure 12, Estonia has one of the highest proportions of ICT graduates in Europe, reaching a peak of 8% of graduates in 2019, significantly above the European Union average in 2019 of 3.9% of graduates reflecting years of investments in pushing Estonian population to adopt ICT and the creation of a favorable ecosystem for digital entrepreneurship.

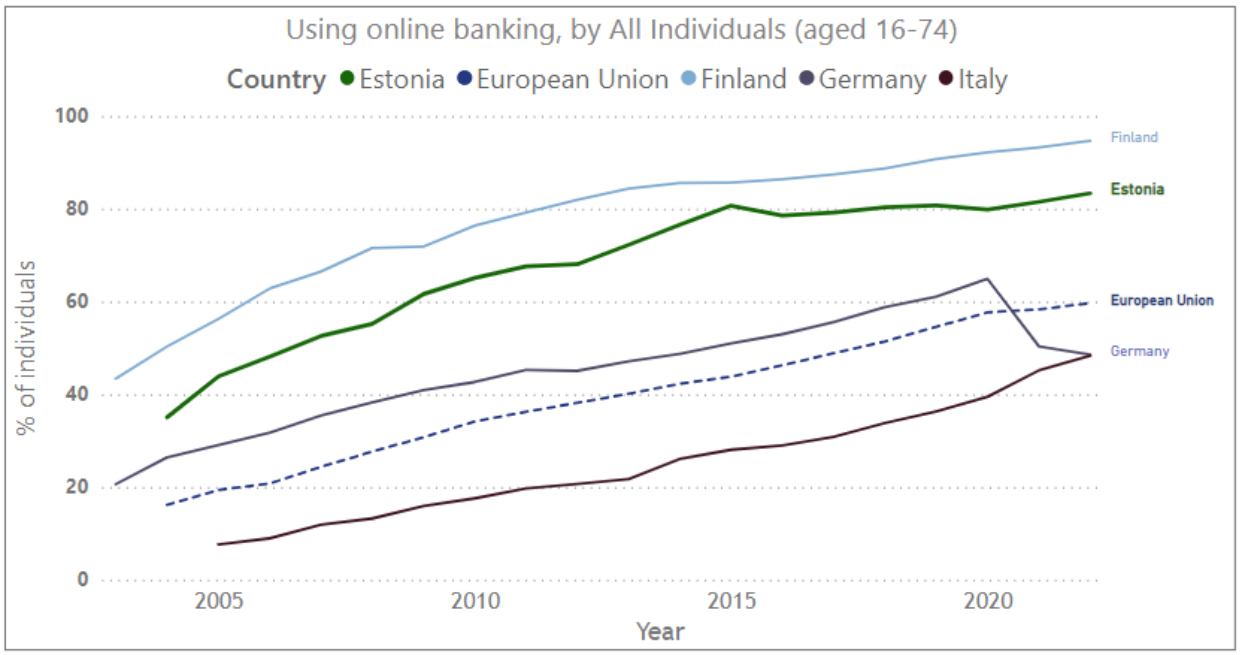
Figure 12. ICT Graduates in Selected European Countries



Source: Digital Economy and Society Index Data Comparison Tool

Beyond the government, other institutional actors have played pivotal roles in shaping the ecosystem of digital services in Estonia. Of note is the Estonian banking sector, which emerged as a key proponent of digital services in the country's early digitalization journey. The banks were among the first to demand robust electronic identification for their users, a requirement that dovetailed with the government's strategy to provide identification services for its population. This convergence of interests laid the groundwork for the integration of digital technologies in the banking sector, accelerating the digitization process. Figure 13 illustrates the percentage of individuals that have used online banking in selected European countries.

Figure 13. Use of online banking by individuals, selected countries



Source: Eurostat – Community Survey on ICT usage in Households and by Individuals

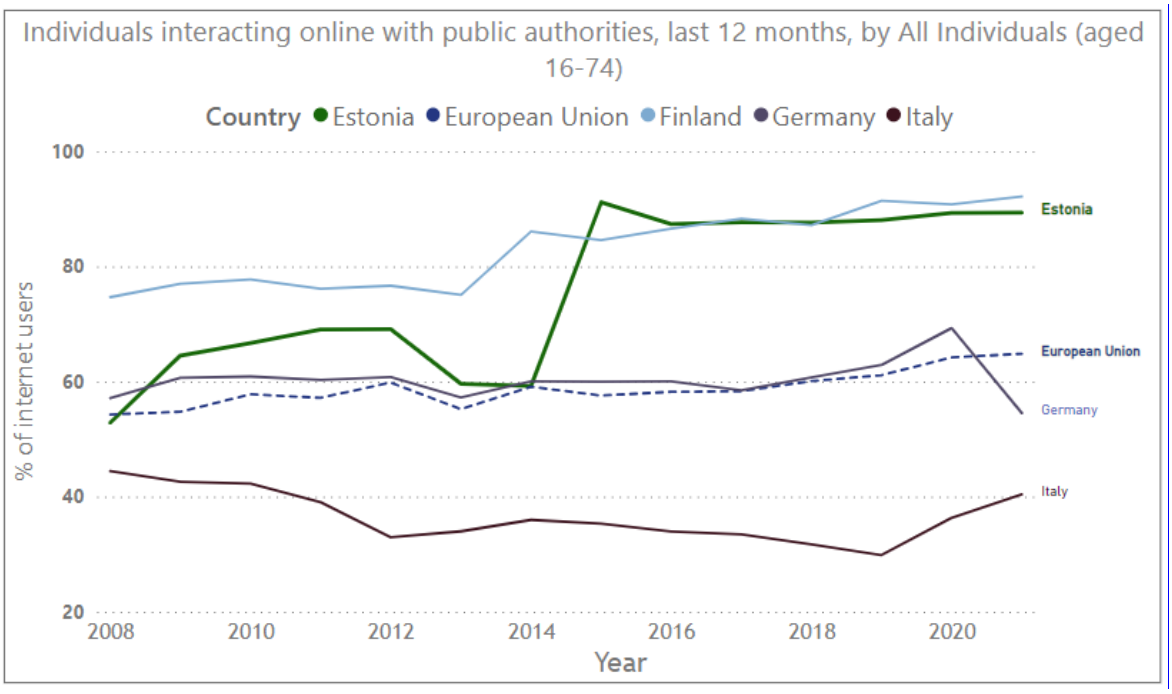
Another notable actor is the Estonian Tax Authority, which distinguished itself as one of the earliest government providers of a widely used, high-impact digital service. The successful implementation and uptake of this digital service provided a significant boost to Estonia's digital transformation efforts, demonstrating the potential for digital technologies to enhance public service delivery (Kitsing, 2011). In the current landscape, Estonia is home to a vibrant tech-based entrepreneurial scene, which further energizes the country's digital ecosystem. The country is home to dynamic technology-based start-ups and unicorn companies, coupled with the broader

institutional and regulatory environment, creates what can be described as 'isomorphic pressures'—forces that drive entities within a given field to resemble one another. These pressures, in turn, illustrate the embeddedness of the Estonian case within a broader context of digitalization.

This multi-actor involvement underscores the interconnectedness of the digital ecosystem and highlights the importance of collaborative synergies between different institutional actors in driving digital transformation. It also attests to the integral role of various stakeholders, from the government to the private sector, in shaping the trajectory of digitalization in Estonia and its implications for the public sector workforce.

Figure 14 shows the percentage of individuals interacting online with public authorities. The use of online interaction with public authorities has several benefits. It can make it easier and more convenient for individuals to access government services. It can also help to reduce the cost and bureaucracy associated with government service delivery. However, some potential challenges are associated with the increased use of online interaction with public authorities. One challenge is ensuring that all individuals have equal access to the internet and the necessary digital skills to use e-government services. Another challenge is ensuring the security and privacy of personal data.

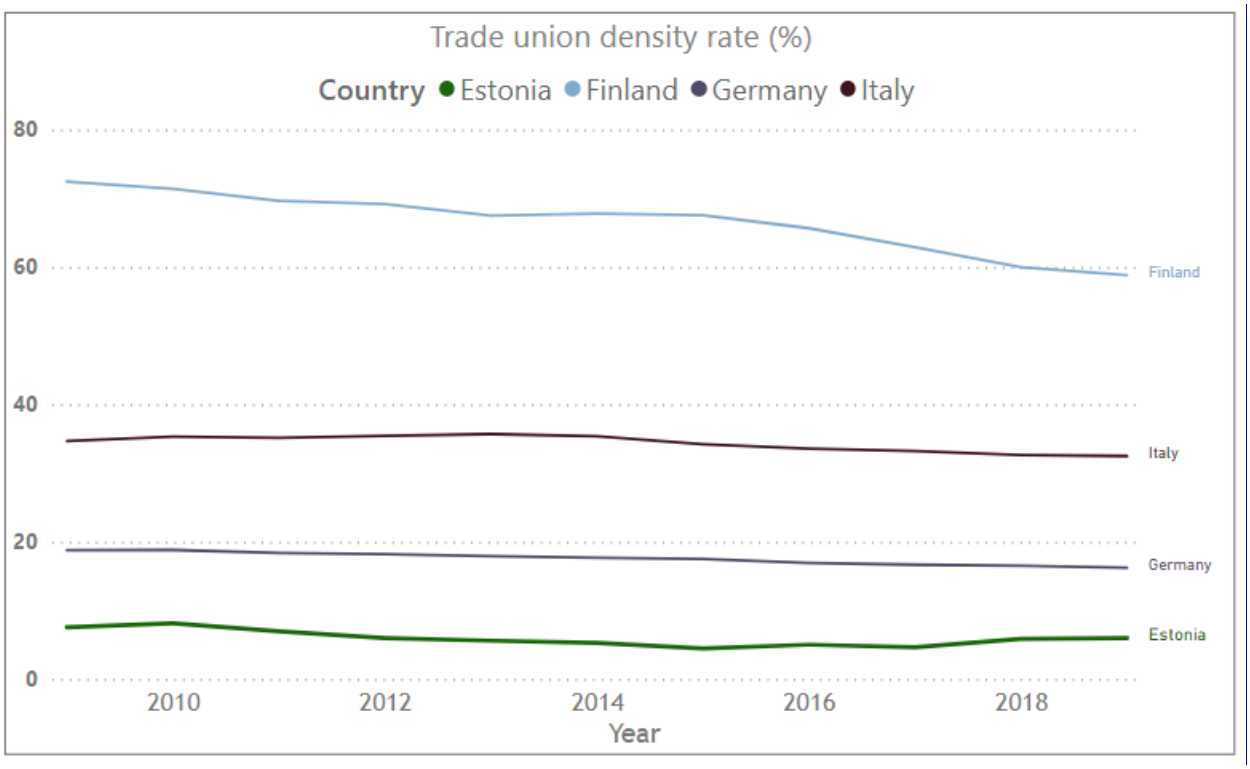
Figure 14. Individuals interacting online with public authorities



Source: Eurostat indicators

Furthermore, Estonia stands out in the European context due to its notably low unionization rate among the working population, one of the lowest in Europe. A true outlier when compared to neighboring countries and regional averages and an important configurational aspect in the Estonian labor market institutions. However additional exploration of this aspect merit further research given the different rates of unionization between public and private sectors.

Figure 15. Trade Union Density Rate for Selected European countries



Source: International Labor Organization, ILOstat

3.3. Case description

Estonia, a modest Baltic republic with a population hovering around 1.3 million, has successfully navigated its journey from regaining independence in 1991 to become a global leader in the sphere of digital governance. This transformation has been a gradual process, with each incremental step aimed at enhancing government functionality and improving public service delivery through digitalization.

The genesis of Estonia's digital journey can be traced back to the visionary 'Tiger Leap' initiative, a government program that prioritized equipping schools across the country with

computers and internet connectivity. This early investment in digital infrastructure and digital literacy laid the groundwork for the comprehensive digital transformation that was to follow. Over the years, Estonia has emerged as a pioneering nation in Europe in terms of privacy and consumer protection legislation. Its commitment to creating a secure, transparent, and user-friendly digital environment has been instrumental in establishing Estonia as a bona fide virtual state. The country's success in digital governance serves as an example for other nations seeking to leverage digital technologies to enhance public sector efficiency and citizen engagement.

The tiger leap program, a government program in the 1997 aimed at providing computers and internet connection to schools in all the country, can be count as one of the probably unintended early policy successes, given the important outcomes in terms of digitalization. Also, in the early 2000s significant investments via Public-Private Partnerships were directed at training almost 10% of the Estonian adult population in ICT skills and increase the internet usage among citizens via the Look@World project. Also, the provision of key digital public infrastructure such as electronic identification, data exchange layer and the offering of digital public and private services enabled by the digital infrastructure helped in increasing the adoption of digital solutions and the making of a digital society (Vassil, 2016). Since 2014 Estonia is counted as an innovation-driven economy according to the World Economic Forum and currently Estonia boasts a very dynamic entrepreneurial scene being the founding place of several unicorns, a name given to technological ventures with a pre-listing valuation of at least one billion U.S. dollars (Kerikmae & Parn-Lee, 2020; Mets, 2017).

As Engin and Treleaven eloquently summarize:

> *[…] Estonia's e-Estonia is an ideal case study of a comprehensive move to digital government or eGovernment. When Estonia regained its independence in 1991, less than half its population had a telephone line. Two decades later, it is a world leader in technology. Estonian geeks [sic] developed the code behind Skype and Kazaa (an early file-sharing network). In 2007, it became the first country to allow online voting in a general election. It has among the world's fastest broadband speeds and holds the record for start-ups per person. Its 1.3 m citizens interact with government services (universally) online; pay for parking spaces with their mobile phones and have their health records stored in the digital cloud. Filing an annual tax return online, as 95% of Estonians do, takes about 3 min. The*

key infrastructure components are a citizen's e-Identity and the e-Services portal. (Engin & Treleaven, 2019, p. 452)

The Estonian case is rich in the combination of diverse elements and layers that enable the digitalization of this country. The amalgamation of various components has significantly contributed to the advanced level of digitalization of public services and society at large. This multi-layered configuration represents the diverse contributing factors and further exemplifies how their unique combination markedly influences the structure and functioning of Estonia's public sector.

The regulatory factors encompass the legal and regulatory framework that Estonia has implemented to support its digital transformation. Thus, enabling citizens, firms, and public administration agencies to take advantage of the potential of digitalization of government functions. Legislation has covered issues like interoperability and access to public information, electronic ID and trust services, security aspects like personal data protection and cybersecurity, the interconnection of base registries, public procurement, and other domain specific legislation. For a quick overview of the Estonian legislation relevant to digital government services please refer to (European Commission, 2022).

The technological factors refer to the technological infrastructure and digital tools (artifacts) that form the foundation of Estonia's digital ecosystem. From cutting-edge software applications to high-speed internet connectivity, the technological aspects encapsulate the advanced tools and systems that enable digital processes and services in the country. In the realm of academic literature, artifacts are described as "bundles of material and cultural properties packaged in some socially recognizable form such as hardware and / or software" (Orlikowski & Iacono, 2001). Essentially, they are the building blocks that work together to create and maintain a functional and efficient digital environment. In the context of Estonia's digital ecosystem, these technological artifacts include key elements like the electronic identification of the population via the eID, and the data exchange layer known domestically as X-Road and the materialization of operational principles such as Digital-First and the Once-Only Principle.

The cultural aspects reflect the societal attitudes, behaviors, and values that support digital adoption in Estonia. It underscores the importance of digital literacy, public trust in digital systems, and the willingness of citizens and businesses to engage with digital services. The cultural aspects

also include transparency attitudes, perceptions of convenience, and postures about data privacy. Each of these components plays a critical role in the widespread acceptance and utilization of digital services by both individuals and businesses. Trust in the government is a cornerstone of digital service adoption. Without confidence in the government's ability to manage and secure digital platforms, citizens and businesses would be reluctant to engage with these services. In Estonia, the government has managed to establish a high level of trust, largely due to its consistent emphasis on security and transparency. This trust has been instrumental in the country's successful digital transformation.

Perceptions of convenience are another important factor. Digital services need to be user-friendly and accessible, otherwise, they risk being underutilized. Estonia's digital government platforms are designed with user convenience in mind, offering streamlined processes that save users time and effort. This emphasis on convenience has made these platforms more appealing, leading to higher levels of adoption. Data privacy is a key concern for any country implementing digital government services. Citizens need to be assured that their personal information will be handled responsibly and securely. Estonia takes data privacy very seriously, implementing robust policies and measures to protect citizens' data.

Finally, the political elements, which include the sustained and broad support over the years to the digitalization agenda by the political leadership in Parliament. The 'isomorphic pressure' argument comes to mind given the early and determinant influence of Nordic countries like Finland in shaping the digitalization path of the Estonian nation. The isomorphic pressure argument can also be seen in the Estonian accession to the European Union which unlocked significant structural funds used in the digitalization effort and the diverse Ministerial Declarations regarding the digitalization of public services such as the Malmö Declaration, Tallin Declaration and Berlin Declaration. The political elements also include the citizens' e-participation in democratic life by proposing legislation and the remarkable levels electronic voting reported in this country. The implementation of the first-ever Data Embassy located in Luxembourg is a key component of the political elements considered. A data embassy allows for the continuity of digital government key infrastructure in case of natural disasters, cyberattacks or military invasion (Kotka & Liiv, 2015).

Moreover, Estonia's approach to digital transformation has also been influenced by cost-reduction strategies commonly employed in the private sector. For instance, the Shared Service

Center model has been a crucial tool in the austerity measures implemented in Estonia following the financial crisis. The State Shared Service Center, a key player in Estonia's organizational architecture, currently manages the European Union structural funds. These funds have played a pivotal role in the evolution of Estonia's digital government. The mandate of the Shared Services Center has been to consolidate and standardize back-office functions. By reaching service agreements with various organizations within the Estonian Central Government, it has been successful in achieving the targeted labor cost reductions, primarily through headcount reductions.

In addition, Estonia's commitment to digital innovation is further exemplified by its artificial intelligence initiative, aptly named "Kratt," or more colloquially, "Burokratt." This initiative is currently delving into the potential of AI technology in the provision of public services. By creating an innovation sandbox, Estonia is effectively harnessing the capabilities of AI technology and the vast amount of citizen transaction data available on the X-Road interoperability platform. The Kratt initiative has drawn comparisons to commercial virtual assistants like Siri, Alexa, and Cortana, but with a distinct focus on the public sector. This comparison underscores the ambition of the initiative: to bring the convenience and efficiency of AI assistants, which are commonplace in the private sector, into the realm of public services.

4. Findings

In this section, we present the background findings in relation to the institutional configuration unique to Estonia, the behavioral interventions and other nudging activities identified by the experts to promote digital government adoption and its implications for the organization of work of Estonian public sector workers. We argue that the unique political, social, and economic configuration of Estonia, the enactment of farsighted regulation and cultural features have determined the very high levels of adoption and the most advanced stages of diverse maturity models thus having an impact on the organization of work of public sector workers.

4.1.Estonia in the 1990s, independence and technological trends

The timing of the regained independence of Estonia and the political goals of the then-youthful leadership to break with the Soviet past are argued as a consequential starting point

towards the current levels of digital government adoption. These events occurred in a decade in which computers and the internet were becoming available out of their traditional customer niche and becoming adopted pervasively by households and firms globally. The digitalization of public services in Estonia can be accounted as the triumph of what political scientist Charles Lindblom discussed as the science of mudding through, or an incremental approach to the develop of a public policy (Lindblom, 1959).

> *""[...] there was something that impacted our ability to be this quick in the digitalization and this was our regained independence in 1991... we didn't become a new country per se, but we became independent. This meant that we could look at freshly all the laws and regulations of the Soviet Union that were in place that were not convenient or effective or efficient for independent Estonia. [...] we had a free-form look at what the government should be like and how it should work. And how we should actually build the future for us and I think that this is one of the things that are very hard. [...] Estonia together with Latvia and Lithuania, we were called the Baltic Tigers for a long time because of our economic growth was immense. And this was because we were able to look at what the future demands are and might be without being held back by the bureaucracy and laws of the past. And I think this was really, really great because it synergized with the advancements in global Internet and technology. So, pairing these two things have definitely made an immense impact on where Estonia is today." (Interviewee # 4, Senior Manager)*

In the early days of the modern Estonian State, the country was to establish a freshly minted democratic regime with significant fiscal constraints and labor and skills shortages an observation associated with the accession to the European Union of the Baltic Republics. In just few years, Estonia enacted legislation crucial to facilitate the development of key infrastructure such as mandatory electronic identification and the X-Road data exchange architecture, provided the regulatory framework for citizens data protection and the outline of the initial digital services provided by the government.

The evolution of the Estonian digital government can be understood as the incremental interaction of diverse parallel processes: *organizational, regulatory, fiscal framework and technical architecture*. A key organizational driver has been the Estonian Information Service Authority (Riigi Infosüsteemi Amet, in Estonian -- RIA.ee) and its institutional predecessors, the

enactment of diverse legislation enabling the provision of public services via digital means and the introduction of operational principles like “digital by default” and the “Once-Only Principle”.

Digital by default and the once-only principle mark a distinct operational convention in which paper is no longer needed in the processing of public services, as one of the interviewees states:

> *“The nature of bureaucracy, which has been a serial or sequential process ever since the first papyrus, you know when you go to an office, and you put in a piece of paper and then from there it goes to the next office and goes to the next office. Someone puts a stamp on it. Digitization means all these things happen in parallel, which gives you huge efficiencies. On both the demand and the supply side.” (Interviewee #6, Senior Government Official)*

The digitalization of Estonian government services should consider a wide variety of technological, institutional, economic, and societal factors. It can be said that there has been some sort of sustained consensus among the political leadership of Estonia supporting digitalization efforts and citizens trusting their government with their data and adopting digital channels for service provision. This configuration of factors and the early success in service design and service provision are deemed crucial to the early evolution and current adoption level in the country.

4.2. Finding 1: The importance of institutional configuration

The interrelation of regulatory, technological, cultural, and political aspects has allowed the current levels of digitalization of Estonian society. Coordination, decentralization, and interoperability outline the organizational process of the digitalization of Estonia, top level coordination for strategy and planning, decentralization for the development, procurement and operationalization phase of service design and service provision, and interoperability via the secure data exchange infrastructure X-Road. The coordination phase might reflect the fact that a significant proportion of digital government developments have been funded by the European Union structural funds, but the development and execution phases has been responsibility of the diverse ministries and their agencies. It is relevant to mention that in Estonia, central government is highly fragmented and decentralized, with much discretion delegated to single organizations, regarding labor practices, each ministry and executive agency is responsible for recruiting,

training, performance appraisal and compensation of its workforce (Pesti & Randma-Liiv, 2018; Randma-Liiv et al., 2015). This decentralized structure of the Estonian central government is considered important in the evolution of digital services, allowing for the technical development of the services to be near the policy domains in which the service was rendered and redesigned to include a digital channel.

> *"Some of the best things that were made over 20 years ago was the decision to make sure that despite us being a very small government, and very small country. The aim was that every ministry and sort of every domain of the public sector has the right to develop its services as needed. This means that the decision was made in IT, the development teams were close to the domains. So, we have ever since we have multiple large IT houses, development centers so to speak and they are developing these services close to the domain itself, which means that the engineers that are developing police information systems for example are more attuned to what are actual police requirements and requirements of interior ministry." (Interviewee # 4, Senior Manager)*

In addition to the issues mentioned above, one salient issue in the digitalization process of Estonia has been the role of banks and telecommunications companies as key actors in the adoption of digital government. The interaction of citizens with the public administration is in general determined by infrequent or occasional "life-events" such as paying taxes or the registration of property. On the other hand, private services like e-banking are more frequent but needed the electronic identification and authentication services provided by the Estonian government.

An early adopter of digital technologies and "flagship success story" of digital transformation in the Estonian government is the Tax and Customs Board. It can be said that tax collection is a relatively easy public service to digitalize and may resemble some service affinity with banking. It may well be equivalent to a transaction via an e-commerce site, caveats should be considered, tax codes differ among countries and jurisdictions. Traditional (paper-based) form of tax declaration was burdensome and if in case of tax refund, it may take months for the refund to be processed and be sent back to the citizens. Filing taxes electronically is not only easier but in the case of refund, it will happen faster. The digitalization of this service was considered convenient and helped to improve the perception of service quality.

In 1997 Estonia launched an educational program named the Tiger Leap aimed at providing Estonian schools with computers, ICT infrastructure, internet connectivity, support for content creation for the development of digital literacy among students and teachers. Sustained investments in the development of ICT skills and digital literacy are part of the institutional configuration found in Estonia. These steps not only helped Estonia to catch up in digital government sophistication with richer neighboring countries (Finland, Sweden, Denmark) but to surpass the capabilities of its digital government vis-à-vis larger European countries.

> *"We primarily attribute our success in digitalization to education. […] we have a lot of visitors in Estonia, different countries, they're looking at digital Estonia and asking about what the cornerstones for the success are. And I always start with education. It's never about, you know, just being good at IT. It's always about education and seldom is the answer that anyone wants." (Interviewee # 4, Senior Manager)*

Estonia has established regulatory safeguards that may have appeased the doubts of its citizens regarding the use and availability of citizens' data by public case officers and third parties. However, trust in government is not homogeneous across countries, and include highly contentious aspects like the deployment of electronic identity mechanisms, a key feature of Estonian digital ecosystem (Axelsson & Melin, 2012).

> *"[...] the trust in our digital systems that has been so many times talked about. This is an emotional feeling, right? It's not a rational thing. There are nowadays governments and countries that have very secure systems introduced and the people do not trust them. [...] (the) Estonian government managed to start providing services that were easy to use and that worked. And if this had not been the case, I believe this trust would also not have, let's say, evolved or developed over time. (Interviewee # 9, Senior Government Official)*

Context and the interpretation of subjective experiences and narratives are crucial. The subsequent remark provides a reflective insight into the intricacies and challenges inherent in adapting Estonian legal frameworks into various national contexts. The interviewee highlights the intrinsic difficulties experienced by individuals from different nations in understanding and learning from the Estonian digitalization path.

> *"People have a very hard time learning from us. Because it's not that like they can take over a law. And translate that to Armenian or Ukrainian or English or what have you. But*

that law is designed to work as part of this Estonian digitalization system." (Interviewee # 1, Senior Manager)

The interaction between public organizations and private companies is a pivotal aspect of digital governance structures in Estonia. The next quotation sheds light on this symbiotic relationship, particularly emphasizing the influential role that private sector entities play in the conceptualization and design of state information systems.

"The state information system is largely designed by private sector companies." (Interviewee # 1, Senior Manager)

In addition, citizens' trust in government, a critical issue in digital government adoption, is particularly high in Estonia, mandatory electronic identification is not a hotly debated issue anymore, instead it is the gateway to a plethora of public (and private services). In Estonia the perception of corruption is low, and citizens and users have enjoyed a regulatory framework regarding privacy and cybersecurity way ahead of its time.

Also, there is a particular aspect found in the interview data, participants hinted at some sort of benevolent revolving door, meaning the movement of high-level employees from public sector jobs to private sector jobs and vice versa in Estonia. Certainly, a practice that would be frowned upon in other jurisdictions but in Estonia managerial capacity, practices and techniques from the private sector are then tested and transferred to a public sector environment supplementing the managerial toolbox of public organizations.

"[...] So basically you see a multi-directional movement and I think this brings the good practices of the private sector into the public sector. [...] in the private sector there are discussions like, should we do waterfall or agile? There is knowledge on how to do it [...] but it's alike in the public sector." (Interviewee # 5, Senior Manager)

Diverse maturity models have been proposed to determine the level of development of digital government, in the literature review of this document we featured that e-democracy and e-participation on one hand, and proactive services on the other were considered the most advanced stage. By these criteria, Estonia leads astoundingly reporting electronic participation and electronic voting mechanisms since 2005. As regards as proactive services, the current configuration of

digital government in Estonia has allowed for the harnessing of massive amounts of data to develop this kind of services through their artificial intelligence initiative Kratt.

In Estonia, it is possible to "map the user journey" by identifying key life-events of the population such as childbirth, business registration, driver's license renewals among others, in which the citizens and users may have to interact with the public administration to initiate a service transaction and kickoff some related administrative processes (subsidies, entitlements, document renewals, etc.) according to their rights and the applicable laws.

> *"[…] if you (are) supposed to get a certain kind of support. You apply and you get it. That's the way it works. Now where it's got interesting is that we've applied AI to it so that it will offer you services you may not even know you need or want." (Interviewee # 6, Senior Government Official)*

> *""[...] related to the AI for example, so we have already like more than 100 use cases. There is a special website for that. It's available in English as well to study all the use cases and this is also part of the service design that services have to be proactive, automated, no user intervention needed. So, AI helps a lot there." (Interviewee # 2, Senior Expert)*

In our examination of the Estonian case, we have pinpointed four pivotal components, delineated in the Table 12: regulatory frameworks, technological dimensions, cultural variables, and political elements. In our interpretation, we deem the regulatory and political factors as institutional enablers, technological factors as enablers from the supply side, and the cultural factors as enablers from the demand side.

Table 12. The Estonian Case Elements

REGULATORY FACTORS	TECHNOLOGICAL FACTORS	CULTURAL FACTORS	POLITICAL FACTORS
☑ Internet as a human right[5] ☑ Mandatory eID[6] ☑ Digital Identity and Digital Signature[7] ☑ Open Government Data and principles for privacy and data security[8] ☑ Digital-by-Default or Digital-First Service Principle[9] ☑ Once-Only Principle[10] ☑ Data Exchange Layer (X-Road)[11] ☑ Cybersecurity Regulation[12] ☑ e-Procurement[13] ☑ Civil Service Act[14]	☑ ID-Card ☑ Mobile-ID ☑ Interoperability through the X-Road data exchange Infrastructure ☑ Public and private services enabled by the Digital Public Infrastructure including the digital signature of documents, online tax declaration, internet banking, health services, application to government aid and thousands of others[15] ☑ Proactive services	☑ High levels of adoption among the citizens[16] ☑ Trust in Government[17] ☑ Transparency[18] ☑ User-centric public service design ☑ From usage data, the identification of life events and population data to design proactive services	☑ Isomorphic pressures via the political effects EU ministerial declarations: Malmö Declaration, Tallin Declaration and Berlin Declaration. ☑ e-Participation instruments ☑ Sustained political support in Parliament for the Digital Agenda ☑ Internet Voting[19] ☑ Data Embassy[20] ☑ NATO Cooperative Cyber Defense Centre of Excellence[21] ☑ Low unionization rate
Institutional Enablers	Supply Factors	Demand Factors	Institutional Enablers

[5] Invest in Estonia: https://investinestonia.com/president-kersti-kaljulaid-access-to-internet-is-considered-a-human-right/
[6] Identity Documents Act 2000: https://www.riigiteataja.ee/en/eli/528122020004/consolide
[7] Electronic Identification and Trust Services for Electronic Transactions Act 2016: https://www.riigiteataja.ee/en/eli/511012019010/consolide
[8] Public Information Act 2000: https://www.riigiteataja.ee/en/eli/529032019012/consolide
[9] General Part of the Economic Activities Code Act 2014: https://www.riigiteataja.ee/en/eli/510072017007/consolide
[10] Principles for Managing Services and Governing Information 2017: https://www.riigiteataja.ee/en/eli/507072017004/consolide and the Digital Agenda for 2030: https://www.valitsus.ee/en/news/government-approved-vision-estonian-digital-society-next-decade
[11] Data Exchange Layer 2016: https://www.riigiteataja.ee/akt/106082019017?dbNotReadOnly=true (In Estonian)
[12] Cybersecurity Act 2018: https://www.riigiteataja.ee/en/eli/523052018003/consolide
[13] Public Procurement Act 2017: https://www.riigiteataja.ee/en/eli/513072020002/consolide
[14] Civil Service Act 2013: https://www.riigiteataja.ee/en/eli/525032019003/consolide
[15] Estonia is a digital society: https://www.visitestonia.com/en/why-estonia/estonia-is-a-digital-society
[16] See (Solvak et al., 2019)
[17] OECD Trust in Government: http://oe.cd/trust
[18] Corruption Perception Index 2022: https://www.transparency.org/en/cpi/2022
[19] For a historical analysis see (Ehin et al., 2022)
[20] First data embassy: https://e-estonia.com/estonia-to-open-the-worlds-first-data-embassy-in-luxembourg/
[21] NATO CCDCOE: https://ccdcoe.org/

4.3. Finding 2: Behavioral incentives and service design

Since the early days of the regained independence of the Republic of Estonia, the ideas towards the digitalization of public administration found a consensus among the Estonian political leadership. As argued above, education played a critical role in the digitalization of schools and the building of digital literacy among the population. Digitalization was identified as a solution to address the need to provide government services amidst the early fiscal constraints of Estonia. Eventually, the early bets placed for digitalization in the rationalization of government services were evaluated during the austerity measures adopted by European countries to address the aftermath of the Global Financial Crisis of 2008-2009 (Tammel, 2017).

Convenience and public services redesign seem to be the most outstanding nudge towards the digitalization of society in Estonia. On one hand, the convenience of the digital channel seemed to be enough to convince end-users to adopt digital services, in general people do not want to wait or stand in a queue. On the second hand, public services design and redesign are considered the "secret sauce" for adoption. The redesign of public services did not mean to replicate what was done in traditional (paper form) but to completely reconstruct the process more efficiently.

> *"Filing taxes online, that's a very direct benefit because I get money faster. I don't have to pre-fill anything ever. Like I wouldn't have to fill practically anything. Everything is pre-filled. I save time. And this is the theme that if there is a very tangible benefit. Then things get used. Things that don't have tangible benefits do not get used." (Interviewee # 1, Senior Manager)*

As interviewee #1 pointed out, the convenience of the digital channel is a powerful incentive for users to adopt these technologies. Examples of these are seen in both the public and private sectors. For the private sector, online banking was a service with quick diffusion given the intrinsic convenience of a frequent transaction via digital means. For the public sector, the tax authority reflects this example of quick adoption of digital services due to the convenience of having tax refund faster than the traditional channels of service.

The evolution of Estonia towards a digital state has come with significant trial and error iterations and some design principles that affect service design and provision like the "no legacy principle" (Kattel & Mergel, 2019). In Estonia, to avoid vendor lock-in and obsolescence of systems, the public digital infrastructure should not use technology older than 13 years, thus

government agencies were committed to embrace a distributed and interoperable architecture of IT and persistent design and redesign of the digital public services in their portfolio in a citizen-centric manner.

> *"Designing the service in a way that people who are using it like it and start using it. But they also have like some kind of training programs for the elderly. I don't know if they have it now, but I remember like 5, 6, 7 years ago, they invited elderly people to show how they can use the ID card to log in and do something like declare taxes [...]" (Interviewee # 5, Senior Manager)*

Digital government services adoption levels in Estonia are incredibly high. Using an Estonian-unique population level dataset, Solvak et al. (2019) found that electronic medical prescriptions are used by 99% of the population, tax declarations by 95%, and around 30% of votes are casted electronically, just to name some of the public services digitally available in Estonia. The information in the forementioned dataset ends in 2015, but we could assume that these adoption rates may have not receded until today.

> *Becoming an e-state has been a stated government goal for well over a decade and state institutions have been strongly incentivized to offer more and more of their services online. At the same time, both public institutions and private companies have encouraged the population to use e-services mainly to cut their business costs. The banking sector has been especially instrumental in making eID usage widespread through encouraging its clients to use more secure identification systems than simple passwords or code cards. Many online services plus a positive image of an innovative e-state does, therefore, encourage persistent linear diffusion growth. Given the highly unusual and theoretically unexpected linear growth pattern, the generalizability of the findings to other contexts ought to be treated with caution.* (Solvak et al., 2019, p. 13)

4.4. Finding 3: Digitalization transforms work in the public sector

It has been conceptualized that digitalization changes the public encounter between citizens and public officials, this is surely the case of Estonia. Years of cumulative investments in the development of digital public services, the high levels of adoption of digital services by the

Estonian population and the intricate institutional unfolding (including fiscal and labor constraints) have changed the public encounter leading to the reorganization of work and the relocation of some front-line employees to back-office operations, especially those involved in clerical tasks.

> *"[...] the specific example is land register and business register because we closed the front offices. So, we used to have like there are a lot of people who were serving the citizens issuing the papers, submitting the papers and communicating with them. But after the registers were digitized, the front office is closed." (Interviewee # 2, Senior Expert)*

The digitalization of government services is not a homogeneous process. Some public services and government agencies may be more prone to digitization, digitalization, and digital transformation due to technical, legal, and cultural constraints. Nonetheless given the case of Estonia in which digitalization of public service is truly pervasive, it may allow us to explore what has been the impact of this level of digitalization in public sector employment.

> *"[...] transformation to digital has forced organizations to change the work processes [...] it doesn't mean that we have fired most of the officials. It just means that they have found other jobs or other tasks within the organization, or the essence of their work has changed. But now we work with data and digital information. This is the part of the work that has changed a lot." (Interviewee # 2, Senior Expert)*

The digital transformation of government operations underscores a pivotal shift not only in the employment structure per se, but also in the qualitative nature of work tasks and processes within organizations. The idea is corroborated by the concomitant rise in the importance of digital literacy and a proficient understanding of basic office software as indispensable competencies within the public sector. Thus, organizations in the public sector need to reskill and upskill their workforce to make the most of the digital technologies being used in the delivery of public services. Additionally, the urgency for upskilling is not limited to mere rudimentary digital skills but extends to more nuanced domains like cybersecurity, data utilization, and artificial intelligence, emphasizing the layered complexity and the expansive spectrum of skills necessitated by digital transformations in contemporary organizational ecosystems.

In addition, after the global financial crisis, Estonia followed a public sector practice found in Canada, Australia, the UK, the US, Denmark, Finland and the Netherlands, the implementation of shared service centers to consolidate back-office functions as instrument for cost reduction. The

cost reductions mechanisms are the reduction in worker headcount; reduction in sparse back-office operations (including the cost of maintaining diverse ICT systems) into a consolidated, economies of scale, tech-enabled service center; and the elimination of redundant processes.

The Estonian State Shared Services Center (Riigi Tugiteenuste Keskus) has a very strong mandate given it is the managing authority for the European Union structural funds in the country and provides accounting, payroll, human resources development, and procurement services for a significant chunk of the Estonian public sector organizations.

> *"[...] Finland had just created there a Shared Service Center for the state. And Denmark. These were the two countries that were most developed this idea by that time. [...] We believe that creating this shared service center together with a common IT solution will help to reduce the number of employees, actually the first goal of the project was to reduce employees dealing with these services by 40%. (Interviewee # 7, Senior Manager)*

Opting to decrease the number of employees, particularly within the public sector, may manifest as a daring and politically contentious endeavor in various jurisdictions, especially when juxtaposed with the context of Western European countries. In many Western European nations, public sector workers typically find themselves as constituents of formidable labor unions, entities characterized by substantial influence and bargaining power. These unions serve as robust protective shields for the rights and interests of the workers, often influencing labor laws and employment policies, and, consequently, acting as significant stakeholders in any discourse related to workforce reductions.

Such potent labor organizations are conspicuous by their absence in the Estonian landscape, rendering the nation's context distinctively different. In Estonia, the absence of such influential labor bodies means that discussions, decisions, and implementations around reducing worker headcount can be perceived through different lenses. The cross-national differences in labor organization structures and their inherent powers and influences are emblematic of the divergent socio-political ecosystems and the varying levels of emphasis placed on worker rights and organizational structures in different jurisdictions.

5. Discussion and conclusions

The Estonian digitalization case demonstrates an incremental and sustained progress towards a bona fide virtual state embedded in a distinctive context, unique path dependencies and institutional features that are difficult to emulate. Research into technology and organizations has revealed that the introduction, acceptance, and utilization of various technologies are deeply intertwined with a multifaceted network of institutional elements, regulatory norms, and cultural traits. These factors can significantly differ across different jurisdictions, thereby influencing the technology adoption landscape. Models that depict the maturity and adoption of technology provide useful frameworks to explain the progression of digital government initiatives. However, they often overlook critical configurational factors, thereby leaving gaps in the comprehensive analysis of the technology adoption journey.

The current state of digitalization in Estonia, thus can be attributed to the evolution institutional elements but also operational principles facilitating the coordination, decentralization, and interoperability of digital government operations. High levels of trust in government by citizens in Estonia is also considered a key aspect in the adoption of digital government solutions.

The case of Estonia serves as a unique example of this phenomenon. The country has charted a distinctive path towards the digitalization of its public services, which may have significantly impacted the adoption trajectory and the operational conditions of public sector employees. The current state of Estonia's digital government is not a sudden or isolated development. Instead, it is the culmination of an ongoing evolutionary process encompassing various aspects such as organizational changes, legal framework adjustments, fiscal framework modifications, and technical architecture advancements. Local experts assert that these intertwined elements have collectively shaped Estonia's digital government landscape. The country's digital transformation journey underscores the importance of considering a broad array of factors when examining the adoption and implementation of technology within governmental and organizational contexts.

Estonia's rapid development and adoption of digital government can be attributed to a combination of strategic early investments and forward-thinking policies. These include substantial investments in education and infrastructure, as well as initiatives aimed at fostering digital skills among the population. These efforts were complemented by a visionary regulatory

framework and an organizational design that was conducive to digital transformation, thereby accelerating the pace of Estonia's journey towards becoming a digital society.

In terms of labor market conditions, Estonia has historically grappled with labor and skill shortages, as well as fiscal and budgetary constraints. These challenges may have contributed to the country's inclination towards digitalization to enhance efficiency and productivity. In essence, Estonia's digital transformation journey is a testament to the interplay of various factors, including strategic investments, regulatory foresight, labor market conditions, and institutional arrangements. These elements collectively provide a comprehensive understanding of the country's successful transition towards a digital government.

The journey towards digital transformation in Estonia has been a multifaceted process, deeply rooted in strategic operational principles, private sector involvement, and a robust IT sector. Principles such as 'digital by default' and the 'once-only principle' have been instrumental in streamlining processes and transitioning towards a paperless bureaucracy. These principles have not only enhanced efficiency but also significantly improved the user experience for citizens interacting with government services.

The role of the private sector in this digitalization journey is of paramount importance and should not be overlooked. There is a clear synergy between the government's digitalization agenda and the private sector's interests, particularly in the provision of services via digital channels. This convergence is evident in sectors such as banking, where digital services have become the norm rather than the exception.

Furthermore, the development of a robust domestic IT sector, with a global reach, has been a key contributor to the creation of Estonia's digital ecosystem. This sector has played a pivotal role in building a comprehensive network of public and private services that are digitally accessible today. In essence, Estonia's digital transformation is a testament to the power of forward-looking regulatory scaffolding, the implementation of strategic operational principles, public-private partnerships, a thriving IT sector and cultural and political forces that have facilitated the profound digitalization of Estonian society. This serves as a compelling case study for other nations to observe while embarking on their digital journeys.

Estonia has successfully navigated the complex path of digital transformation by striking a delicate balance in its approach. This balance is characterized by strategic coordination in

planning, decentralization in development and operations, and interoperability among a diverse array of stakeholders. These elements have collectively contributed to the maturity and success of Estonia's digital government. The advanced stage of Estonia's digital government has paved the way for the exploration of data-driven projects. A prime example of this is the provision of proactive services. Unlike traditional services that are initiated by a citizen's request, proactive services leverage advanced data analytics techniques, such as artificial intelligence and machine learning, to identify a citizen's needs. These services are then "pushed" to the citizen for completion, thereby enhancing efficiency and user experience. This innovative approach to service delivery underscores Estonia's commitment to harnessing the power of technology to improve public services and unequivocally changing the public encounter between citizens and public sector workers.

The experimental deployment of artificial intelligence applications in public service provision is a testament to Estonia's forward-thinking approach to digital governance. It not only showcases the country's commitment to leveraging cutting-edge technology but also highlights its dedication to improving the citizen experience through digital innovation.

In sum, Estonia's journey towards digital transformation has significantly reshaped the interaction between citizens and public sector workers. The advanced stages of digital government adoption and maturity, coupled with changes in labor market institutions and the redesign of bureaucratic processes due to digitization, digitalization, and digital transformation, have all contributed to this shift. In particular, the role of front-line employees, especially those involved in clerical tasks, has undergone a significant transformation. As users increasingly prefer digital channels for their interactions with the public sector, these workers have been reassigned to new tasks. This shift not only reflects the changing dynamics of public service delivery but also highlights the adaptability of the workforce in response to digital transformation. Estonia's unique experience underscores the profound impact of digital transformation on the public sector. It serves as a reminder that the journey towards digital government is not just about implementing new technologies, but also about rethinking institutions, redesigning processes, and reshaping interactions between the citizens and government organizations.

However, it's important to note that the digital transformation has not resulted in the dismissal of public sector employees whose work has been impacted by digitalization. Frontline

public workers, who are no longer tasked with dealing directly with the public, have been reassigned to alternative tasks within public administration. This reassignment underscores the adaptability of the public sector workforce in the face of digital transformation.

In conclusion, the impact of digital transformation on the Estonian public workforce cannot be fully understood without considering its deeply embedded context, or the Estonian case discussed above. The high levels of digitalization of government services in Estonia are not a sudden phenomenon, but the result of decades of strategic investments and thoughtful planning. These investments have spanned various areas, including education and training, which have been instrumental in equipping the workforce with the necessary digital skills. The design and redesign of public services have also played a crucial role, ensuring that digital solutions are effectively integrated into service delivery mechanisms. Key operational principles have been implemented to guide the digital transformation process, ensuring that it aligns with Estonia's broader strategic objectives. The configuration of labor market institutions has also been adjusted to support the digitalization process, demonstrating the country's adaptability in the face of change. Perhaps most importantly, the political and societal acceptance of digital solutions has been a critical factor in facilitating the provision of public services. This acceptance underscores the importance of fostering a culture that embraces digitalization, recognizing its potential to enhance efficiency, improve service delivery, and ultimately, better serve the needs of citizens by creating public value by the harnessing of powerful digital technologies.

5.1. Practical recommendations

This study underscores the significance of institutional and cultural factors in the digitalization process. Despite relatively similar levels of technological diffusion, adoption rates can vary significantly. Public administrations across Europe are advancing toward the digitalization of their services, yet they do so within unique contextual configurations and path dependencies. These complexities challenge traditional comparative methods, necessitating a more nuanced approach to understanding digital transformation across different jurisdictions. Nevertheless, the implementation of the Digital Agenda for Europe is fostering a degree of harmonization in public services at the regional level. This harmonization is an important step

towards creating a more unified digital landscape across Europe, but it also highlights the need for further research to understand the specific impacts and implications of these changes.

The study of individual cases like Estonia, despite their inherent limitations, can offer rich insights into the complex dynamics of digital transformation in the public sector. These insights can, in turn, inform more effective strategies and policies for harnessing the potential of digital technologies to enhance public service delivery. As we continue to navigate the digital era, such research will play a crucial role in shaping our understanding of these dynamics and guiding policy and practice in the public sector.

The digitalization of public services and its subsequent effects on the workforce is neither homogeneous nor predictable. These processes are often subject to powerful institutional and organizational inertia, which can shape the trajectory and outcomes of digital transformation in unique ways. Given this complexity, it is both timely and relevant to embark on a research agenda that seeks to deepen our understanding of these dynamics.

This study yields several practical recommendations that underscore the growing relevance and research output in the field of digital government. As a multidisciplinary domain, digital government is tasked with addressing a myriad of complex and multifaceted issues. With the advent and incredibly fast diffusion of Generative Artificial Intelligence such as Large Language Models (LLMs) and other automation technologies for knowledge work, the study of the impact of automation technologies on the government workforce may prove a rich research field to pursue and explore through a robust research agenda.

The field of digital government presents a rich and largely untapped area for further academic exploration, particularly concerning the impact of digitalization and other related technologies on the government workforce. Future research in this area will not only contribute to academic discourse but also provide valuable insights for policymakers and practitioners navigating the complexities of digital transformation in the public sector.

In general, public-sector work is situated within a complex context, characterized by an intricate interplay of power dynamics, ideological perspectives, design considerations, and institutional changes. These factors must be considered when examining the functioning and transformation of public sector organizations. Governments are equipped with a variety of institutional instruments and are tasked with addressing public policy goals that often resemble

"wicked problems." These are complex, multifaceted issues that defy straightforward or singular solutions. The inherent complexity of these problems is further compounded by budgetary constraints and other limiting factors, adding additional layers of complexity to the task at hand.

Moreover, the public sector operates within a unique set of constraints and pressures, including political accountability, public scrutiny, and the need to balance efficiency with fairness and accessibility. These factors can significantly influence the strategies and approaches adopted by public sector organizations, and they add to the complexity of implementing change within this context. In sum, the public sector presents a uniquely challenging environment for the implementation of digital transformation and other forms of organizational change. A comprehensive understanding of these complexities is crucial for developing effective strategies and approaches for public sector reform. Future research and practice in this area will need to grapple with these complexities and seek innovative solutions that can navigate the intricate landscape of public sector work.

In nations that have achieved high levels of government digitalization, for example European countries, a phenomenon known as isomorphic pressure is propelling public digital services toward greater sophistication and quality. This pressure, which emanates from peer organizations or leaders in digital organizations, encourages entities to emulate successful models and adopt best practices in digital service provision. Estonia serves as a prime example of this dynamic. The country boasts one of the most vibrant entrepreneurial ecosystems globally and has established itself as a leading brand in societal digitalization. The Estonian experience provides a compelling case study of a comprehensive and successful path to digitalization. However, as we continue to navigate the digital era, it is crucial to not only identify the key building blocks in the direction to full-fledged digitalization but also to map potential developments in emerging areas. These include artificial intelligence and proactive services, which hold significant potential for transforming public service delivery.

The digitalization journey is a complex and ongoing process, influenced by a range of factors including isomorphic pressures, entrepreneurial ecosystems, and emerging technologies. A comprehensive understanding of these dynamics is crucial for navigating the path toward digitalization and harnessing the potential of digital technologies to enhance public service delivery and the organization of work in public organizations. Future research in this area will play

a crucial role in shaping our understanding of these dynamics and informing policy and practice in the digital era.

5.2. Limitations and future research

While single-case studies may lack the comparative perspective offered by multi-case analyses, they can nonetheless reveal critical configurations that can inform further exploration of the subject matter. As demonstrated in this chapter, the elements of Estonian digitalization represent a unique and intricate configuration of regulatory, technological, cultural, and political layers. This complex interplay has facilitated Estonia's advanced level of digitalization and its consequential effects on the organization of work in the public sector. The continued exploration of the impacts of digitalization on public-sector employment can provide valuable insights for policymakers and citizens alike. Such research can illuminate policy options, best practices, necessary human capital investments, and required legal amendments to optimize the use of digital technologies in the public sector.

The public sector is a significant user of Information and Communication Technology (ICT) and employs a substantial number of individuals. Existing research in organizational studies and economics suggests that ongoing incremental digitalization is transforming both the organization of work and the workforce. Yet, empirical exploration of these transformations within a public sector context is limited. A significant proportion of academic work investigating the interplay between modern technologies and labor is situated within a market environment. This focus may overlook the unique dynamics and challenges present within the public sector. Therefore, there is a pressing need for more comprehensive research that specifically examines the effects of digitalization on the public sector workforce.

There is a pressing need for further exploration into the impact of digitalization on the public sector workforce given the most recent technological developments. This area remains relatively underexplored, despite its critical importance. Future research could benefit from alternative methods that more effectively address the complexities and nuances of digital transformation in the public sector. A deeper understanding of these factors and their impacts on the public sector workforce will be crucial for navigating the ongoing digital transformation in Europe and beyond.

One promising avenue for exploration is the development of a taxonomy of public services within a jurisdiction that is most amenable to digital transformation. Such a taxonomy could provide valuable insights into the types of services that are most likely to benefit from digitalization and the specific factors that make these services ripe for transformation. This could include factors such as the nature of the service, the characteristics of the user base, and the technological infrastructure in place. This taxonomy could also inform strategies for human capital formation, investment in skills, and public service redesign. By identifying the services most prone to digital transformation, policymakers and practitioners can target their efforts more effectively, ensuring that investments in skills and service redesign are aligned with the areas of greatest potential impact.

In addition, the role of emerging technologies such as artificial intelligence and machine learning in public service design warrants further exploration. These technologies hold significant potential for transforming the way public services are delivered, enabling more personalized, efficient, and proactive services. Research in this area could examine the potential applications of these technologies in public service delivery, the challenges and opportunities associated with their implementation, and the implications for the workforce and service users.

In conclusion, the digitalization of public services and its effects on the public workforce presents a rich and complex research agenda. By exploring the taxonomy of services most prone to digital transformation, the role of emerging technologies in service design, and the implications for human capital and service redesign, we can deepen our understanding of these processes and inform more effective strategies for digital transformation in the public sector.

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Appendix 3. Interview Protocol

Script 1 Introduction

Greetings

Thank you for your time.

Self-introduction by researcher.

Research Aims: My research explores the impact of digitalization in the public sector workforce. The digitalization process of Estonia has been chosen due to the high level of digitalization in the public sector as reported by the United Nations E-Government Development Index and the European Commission Digital Economy and Society Index (DESI).

Informed consent: Anonymity / Information codified / Informed consent (Y/N)

Confidentiality: After the analysis of the data the purpose is publication. **Anonymity will be granted** for the publication of results.

Introduction

Please state **your name**, **current position**, and a **brief outline of your career** (years of experience) ***within or about*** the Estonian public sector (if a contractor).

Semi-structured interview questions

1) What formal institutional factors[22] have facilitated the incremental digitalization of public services in Estonia?

2) What informal institutional factors[23] have facilitated the adoption and diffusion of digital public services in Estonia?

3) What type of behavioral interventions, incentives or "nudges" have been applied by the Estonian government to accelerate the adoption of digital services by citizens and firms?

4) What has been the role of private sector workers (as contractors or as outsourced work) in the digitalization of public services?

[22] Regulation, institutional design among others.
[23] Culture, political ideology, values (trust in government) among others.

5) How has the digitally enabled co-production of public services changed the organization of work[24] in the public sector?

6) What functional group[25] of the Estonian public sector has experienced the most significant changes in its workforce due to digitalization?

7) How has the digitalization of public services changed the skills demand for public sector employees?

Script 2 Conclusion

Thanks again. There may be a subsequent contact if there is need to clarify information.

Script to say before and during the conclusion of the interview.

AFTER

Transcription made. Send copy of transcript to interviewee. Member check and feedback.

[24] For a definition: https://www.eurofound.europa.eu/topic/work-organisation
[25] Use of Classification of the Functions of Government (COFOG) handout to illustrate this.

CHAPTER V - CONCLUDING DISCUSSION

1. Introduction

This chapter serves as a summary of the research journey embarked upon in this dissertation, synthesizing the insights gleaned from the diverse methodologies employed, including Structural Topic Modeling, panel data analysis, and qualitative case study examination. It seeks to weave together the threads of understanding developed in each individual chapter, presenting a cohesive narrative that illuminates the complex dynamics at play between digitalization and the public sector workforce.

The exploration of the relationship between digitalization and the public sector workforce is not a monolithic investigation, but rather a multifaceted inquiry that spans different methodologies, geographical contexts, and levels of analysis. This chapter aims to showcase this diversity, underscoring the breadth and depth of the investigation conducted.

The diverse methodological approaches applied to our subject of inquiry helped us in our goal to understand if digitalization is a labor-saving technology in a public sector context. Automation technologies such as digitalization and artificial intelligence are becoming diffused and used in European governments at national, regional, and local levels thus changing the public encounter, the relationship between citizens, and the public administration with potential effects on public sector occupations.

First, given the ever-increasing research output in most fields of science, we conducted a computational approach to literature review known as Structural Topic Modeling, a technique that allows for the systematic analysis of large quantities of text data, including bibliographic data and metadata. To the best of our knowledge, this study marks the first attempt to employ unsupervised machine learning techniques like topic models in a Digital Government Research corpus.

Moreover, the programmatic nature of this approach enhances the reproducibility of the literature review process. By using a computational method to review the literature, researchers can provide a clear record of the steps they took, the parameters they used, and the decisions they made. This transparency not only enhances the credibility of the literature review but also allows other researchers to replicate the review, test the robustness of the findings, or adapt the method to

their own research questions. In essence, this automated approach to literature review and evidence synthesis represents a significant advancement in the way researchers can navigate, understand, and contribute to their respective fields in the face of the ever-growing research literature.

Second, following a quantitative approach using panel data for 20 European countries, we explored the relationship between a United Nations flagship digital government indicator, the E-Government Development Index, and selected public employment indicators from the World Bank's relatively novel dataset: the Worldwide Bureaucracy Indicators in European countries at the national level.

Third, following a qualitative approach, we considered Estonia (a regional leader in e-government metrics) as our single case study to explore in depth the institutional factors found in this country that have enabled profound levels of adoption and use of digital public services among its population and how this advanced level of digitalization has transformed the public sector workforce and the organization of work in Estonia.

2. Summary of Findings

From Chapter 2, the analysis of over 6,600 abstract texts from journal articles in the Digital Government Reference Library revealed key themes and research topics in Digital Government literature. Among the thirty topics explored through topic modeling, four are related to automation technologies such as artificial intelligence, cloud infrastructure, blockchain, and the Internet of Things. These topics show an increasing relevance in the corpus over time. Additionally, one topic related to employment and work was identified. Nonetheless, the graphical analysis with the LDAvis software shows a lack of overlap between the topics related to automation technologies and the topic related to work and employment in the public sector. We interpret that these topics have not been covered in tandem in the corpus indicating an opportunity in a relatively new and promising subfield in extant literature. Opening an opportunity to explore the relationship between automation technologies and the public sector workforce.

From Chapter 3, the analysis of public employment indicators in 20 European countries from 2008 to 2018 reveals that digitalization does not seem to be a labor-saving technology in the European public sector in aggregate terms. However, when explored at an occupational level, the

data suggest a polarization between high-skill and low-skill occupations and by educational tier. Digitalization has a negative and significant effect on the public sector wage bill suggesting that digitalization allows for the automation of some tasks, reducing the need for human labor and thus reducing the overall incidence of labor costs. It could also be that digitalization leads to the reorganization of work processes, which might reduce the number of employees needed in some tasks.

From Chapter 4, our analysis, based on interviews with nine subject matter experts and the analysis of secondary sources, reveals that digitalization has changed the way public services are rendered in Estonia. It has transformed the functions and task content of street-level bureaucrats and other public sector workers and has led to the redesign of public sector front-office, back-office, and support services into a digitally enabled shared service model. Important caveats do apply. Estonian case is framed in powerful path dependencies and institutional factors fostered over decades.

3. Implications of Findings

Novel computational techniques such as topic models are helping researchers to improve the scope of the analysis and questions addressed to an ever-growing amount of data. Digitalization is also changing the way research is conducted and communicated. Reproducible methods for research contribute to the robustness and replicability of findings. In the literature review conducted for this dissertation, the most salient issue is the lack of overlap between the topics related to automation technologies in the digital government corpus and the topic related to work and employment. A combination of these two streams of literature is what generated the initial curiosity in exploring how automation technologies affect public sector occupations. This combination of research fields could prove to be a new and promising subfield to pursue in further inquiries opening an opportunity to explore the relationship between automation technologies and the public sector workforce with the opportunity of creating a robust research agenda for upcoming years.

The findings from the panel data exercise suggest that digitalization allows for the automation of some tasks, reducing the need for human labor and thus reducing the wage bill. It could also be that digitalization leads to the reorganization of work processes, which might reduce

the number of employees needed. As for the polarization observed in the analysis, we interpret the results as a mirroring effect of the results found in a market context. Our exploratory analysis seems to suggest that the combination of technological, political and institutional factors characterizing digitalization and automation processes in the public sector might determine a significant diversity in labor force patterns across tasks and across countries.

The Estonian case study highlights that a complex array of institutional factors and very high adoption levels by the population has altered the traditional interaction among citizens, organizations, and the State. This transformation not only signifies a shift in the mode of service delivery but also signals a fundamental change in the working dynamics of the public sector workforce.

4. Methodological Contributions

The application of Structural Topic Modeling (STM), a computational method that originated in the field of Computer Science, has demonstrated its immense potential as a powerful interdisciplinary tool in this dissertation. STM is a technique that leverages the capabilities of machine learning to process and analyze vast quantities of text data, distilling it into a set of key themes or topics. This technique provides a strategic lens for the systematic examination of the ever-growing corpus of scientific literature, enabling researchers to navigate the complexities of large-scale text data and uncover meaningful patterns and insights.

In the context of this dissertation, the use of STM has proven to be particularly valuable. It has facilitated a comprehensive and objective review of the literature on digital government research, allowing for the identification and quantification of various topics in a selected corpus. By doing so, it has enabled the research to delve deep into the intellectual structure of the field, explore thematic evolution over time, and identify dominant and emerging topics in the literature. This has not only enriched the understanding of the field but has also helped identify promising areas for further research.

Moreover, the dissertation has also incorporated digital technologies into the research process itself, demonstrating a forward-thinking approach to academic research. Specifically, reproducible workflows for data management were employed for the research presented in

Chapters 2 and 3. This approach ensured that the research process was transparent, efficient, and robust, allowing for the tracking and documentation of all iterations of the research process. This not only enhanced the integrity and validity of the research outcomes but also ensured that the research process could be replicated by other researchers, contributing to the broader academic discourse on reproducibility in research.

In addition, automated transcription services were utilized for the qualitative analysis conducted in Chapter 4. This innovative approach to data collection not only enhanced the efficiency of the research process, but it is also a testimony of the increasing capability of artificial intelligence technologies into accelerating data processing and data analysis in research. The incorporation of computational approaches to research programs has the potential to empower early-stage researchers and research teams into creating more valuable and higher-impact research and at the same time further enhance the transparency and reproducibility of the research enterprise.

5. Limitations and Future Research

Topic modeling is not free of limitations. Diverse biases, discussed and acknowledged in Chapter 2, could be introduced in the data acquisition, treatment, processing, and communication of findings workflow. Nonetheless, computational tools and reproducible workflows are improving the research repertoire of researchers, helping to mitigate the reproducibility crisis, and providing robust frameworks for data management in the research endeavor.

In Chapter 3, due to the lack of detailed and comparable data, and data aggregation complexities, and more specific data aggregation, some of the findings may mask significant differences among public sector occupations. The European public sector is diverse in composition, scope, mandate, and labor market institutions are embedded in national contexts that have not been considered for this analysis. Future research could delve into comparable open government data to address these differences and contexts and contribute to further exploration of the interaction of digitalization and public sector workforce indicators. Data granularity is necessary to provide additional insights and comparability at a sectoral and organizational level.

Chapter 4 of this dissertation centers on an in-depth exploration of a single case study - Estonia. While the focus on a single case study provides a rich, detailed, and nuanced understanding of the effects of advanced digitalization in a specific context, it does inherently limit the generalizability of the findings. The insights assembled from the Estonian case are deeply intertwined with the country's unique socio-political, economic, and institutional landscape, and as such, may not be directly applicable to other countries or regions.

However, this limitation also opens avenues for future research. The exploration of the Estonian case provides a blueprint for similar investigations in other countries or regions that share similar institutional compositions, levels of technological readiness as well as facing similar institutional challenges and bottlenecks. Future research could replicate the methodology employed in this chapter to explore the effects of advanced digitalization on the public sector workforce in these contexts. Such comparative studies could provide valuable insights into the commonalities and differences in the impacts of digitalization across different contexts, enhancing the generalizability of the findings.

The subject matter of this dissertation, the exploration of the relationship between digitalization and the public sector workforce, is situated at the intersection of several vibrant and dynamic disciplines and fields of scientific inquiry. These include, but are not limited to, information systems, public administration, political science, economics, and innovation studies. Each of these disciplines brings its unique perspectives, methodologies, and theoretical frameworks to the table, enriching the understanding of the complex dynamics at play.

This interdisciplinary nature of the research topic presents a unique opportunity for academic cross-pollination and collaboration. Scholars from diverse fields can come together to share their insights, challenge each other's assumptions, and build on each other's work. This collaborative approach can lead to the development of innovative solutions to common scientific, technical, and methodological challenges.

Moreover, this cross-disciplinary interaction can also serve as a catalyst for theory development. The convergence of different theoretical perspectives can lead to the emergence of new theories that capture the complexity of the relationship between digitalization and the public sector workforce. These theories can provide a more holistic understanding of the phenomenon,

considering the diverse factors at play, from the technological and economic to the social and political.

Furthermore, the interdisciplinary nature of the research topic also opens avenues for broader societal collaboration. Policymakers, practitioners, and industry leaders can engage with academic researchers to translate the findings of the research into practical strategies and policies. This can ensure that the benefits of digitalization are maximized, and any potential negative impacts on the public sector workforce are mitigated.