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Digital public services: Catalysts for healthcare efficiency

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ABSTRACT

Healthcare systems pose a continuous concern and challenge for countries worldwide. Effective governance plays a pivotal role in managing these systems, ensuring the well-being of current and future generations. In this context, digital transformation emerges as a key catalyst for change. E-government, with its potential to foster integrated policies and public services, holds the promise of driving healthcare transformation and improving healthcare delivery efficiency. This study aims to comprehensively analyze the impact of e-government on healthcare transformation within the context of 27 European Union (EU) countries over the period from 2011 to 2022. Leveraging a Tobit model, the results showed that the development of e-government is a positive determinant for a country's ability to achieve transformative changes in its healthcare system. The findings of this study underscore the pivotal role of digital public services in reshaping healthcare systems and advancing the delivery of healthcare services. As nations strive to meet the evolving needs of their populations and enhance the sustainability of healthcare, e-government emerges as a powerful enabler of change. This research contributes to the growing body of evidence supporting the integration of e-government in healthcare systems, promoting the efficient, effective, and equitable delivery of healthcare services. It provides valuable insights for policymakers and stakeholders, emphasizing the importance of prioritizing digital transformation to drive healthcare improvements, ultimately benefiting both present and future generations.

1. Introduction

In the digital age, the integration of technology into public services has become a cornerstone for enhancing operational efficiency and service delivery across various sectors, with healthcare being no exception. The advent of digital public services, particularly e-government initiatives, has ushered in a transformative era for healthcare systems worldwide (Letunovska et al., 2023). The potential for these initiatives to streamline healthcare administration, improve patient care, and facilitate access to health services is increasingly being recognized. According to a report by the World Health Organization (WHO) (2021), digital health technologies are pivotal in strengthening health system efficiency, evidenced by a 40 % increase in patient outreach through telemedicine in over 60 % of countries surveyed. The emergence of digital public services, especially e-government initiatives, heralds a new epoch in global healthcare, characterized by enhanced service accessibility and administrative efficiency. The European Commission (2023) highlights that e-health applications have the potential to improve healthcare quality by 20 %, as digital records reduce clinical errors by approximately 25 %. These initiatives are lauded for their capacity to refine healthcare management, elevate patient care standards, and democratize health service accessibility. The integration of electronic health records (EHRs) alone has revolutionized patient information management, with a 30 % improvement in administrative efficiency reported across healthcare facilities implementing EHR systems (Boulus-Rødje, 2019; Joukes, 2019). This digital transformation not only streamlines healthcare delivery but also fosters a patient-centered approach, significantly broadening the scope of accessible healthcare services and ensuring that quality care extends beyond the confines of traditional medical facilities. According to some studies (Letunovska et al., 2022; Kwilinski et al., 2023a), the digitalization of healthcare systems is multifaceted, requiring not just the integration of technology but a holistic approach that encompasses the development of relevant knowledge (Dacko-Pikiewicz, 2019; Kwilinski,

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2023), the provision of adequate resources (Tresp et al., 2016; Blix and Levay, 2018; Hossain et al., 2022; Patel et al., 2023), the implementation of strategic management (Miśkiewicz, 2019; Trzeciak et al., 2022; Dzwigol, 2023), and the establishment of a resilient infrastructure (Tortorella et al., 2022; 2023; Kwilinski et al., 2023b). Healthcare professionals must be equipped with advanced digital skills (Mohsen et al., 2018; Sapci and Sapci, 2019; Jain, 2020; Roda, 2021; Anastasiou and Smith, 2023; Burzyńska et al., 2023; Letunovska et al., 2021) and continuous education to keep pace with evolving technologies, ensuring they effectively utilize digital tools for patient care and data management. Moreover, the successful adoption of digital healthcare solutions hinges on the availability of sufficient resources. This includes financial investments (Moskalenko et al., 2022; Kwilinski and Trushkina, 2023) for the procurement of state-of-the-art technologies, ongoing maintenance costs, and funding for research and development to innovate and improve digital healthcare services. Beyond financial capital (Letunovska et al., 2022; Kwilinski et al., 2023a; Moskalenko et al., 2022; Kwilinski and Trushkina, 2023), resources also encompass the technological tools and platforms that facilitate telehealth services, electronic health records (EHRs), and other digital health applications. Effective management plays a critical role in the seamless integration and utilization of digital technologies within healthcare settings (Cormican et al., 2023; Kumar et al., 2023; Fanelli et al., 2023; Sandoval et al., 2023; Alowais et al., 2023; Dion et al., 2023). Leadership within healthcare organizations must champion digital initiatives (Denicolai and Previtali, 2023; Wymer et al., 2023; Yansen and Yujie, 2023; Rodriguez et al., 2023), fostering an environment that encourages innovation and the adoption of digital solutions (Trushkina et al., 2020; Kharazishvili and Kwilinski, 2022; Szczepańska-Woszczyna and Gatnar, 2022; Kwilinski, 2023b).

Digitalization, while revolutionizing healthcare and other sectors, inadvertently stimulates the overconsumption of energy resources (Hussain et al., 2021; Zhanibek et al., 2022; Kwilinski et al., 2022a). This surge in demand for energy contributes to increased greenhouse gas emissions and environmental degradation. The environmental impact of such digital expansion is significant; as energy consumption rises, so does the carbon footprint of digital operations, exacerbating climate change and its associated health risks (Khatib, 2023; Kotsila and Anguelovski, 2023; Morello-Frosch and Obasogie, 2023). This chain of events, in turn, leads to an increase in mortality rates, as populations become more vulnerable to the health consequences of a changing climate, including respiratory and cardiovascular diseases, heat-related illnesses, and vector-borne diseases. Therefore, while digitalization offers numerous benefits, it also poses environmental challenges that need to be addressed to mitigate adverse health outcomes and ensure a sustainable digital transformation. Therefore, an effective digital policy, especially within the healthcare sector, addresses the outlined challenges. This study focuses on examining the effects of digital public services on healthcare, aiming to identify how strategic digital service implementation can enhance healthcare efficiency. It draws on insights from both successful and problematic applications of digital technology in healthcare settings, offering a comprehensive view of how digital innovations can be optimally integrated into healthcare systems. This study addresses a gap in the theoretical understanding of healthcare efficiency by empirically demonstrating the positive influence of digital public services on healthcare efficiency. The main contributions of this paper are twofold: 1) it addresses a limitation of the traditional Data Envelopment Analysis (DEA) model, which does not account for input and output slackness and may indicate healthcare efficiency scores greater than one for some countries. By employing the Malmquist Productivity Index, the study effectively resolves these issues, offering a more nuanced measurement of healthcare efficiency; 2) the study provides a quantitative measurement of healthcare efficiency, utilizing the results to develop strategies and recommendations aimed at enhancing healthcare efficiency within the EU through digital public services. This approach offers a scientific foundation for policy development and decision-making in the realm of healthcare efficiency improvement.

The paper has the following structure: Section 2 explores the theoretical framework of measures of healthcare efficiency and the impact of digital public services on healthcare efficiency; Section 3 contains a justification of the methods, the instrument, data, and sources for analysis; Section 4 explains the results of analysis of the impact of digital public services on healthcare efficiency; Section 5 compares the obtained findings with the previous studies; and Section 6 summarizes the results of the investigation, policy implication, limitations and further directions for investigation.

2. Literature review

2.1. *Efficiency of Healthcare*

Liu et al. (2012) analyzed the efficiency of healthcare through a comparison between the efficiency of government healthcare expenditure and individual out-of-pocket (OOP) expenses, using Data Envelopment Analysis (DEA) and the Panel Tobit model. Liu et al. (2012) revealed that while government expenditure in healthcare shows improved efficiency, the efficiency of OOP expenses is on the decline, which impedes progress in making healthcare services more affordable and accessible. Liu et al. (2012) underscored the necessity for the government to implement specific measures aimed at enhancing the efficiency of OOP expenditures, especially in central and western areas of China, to reduce the financial burden on citizens. Bortoletto and Favaro (2019) investigated the efficiency of healthcare systems across Europe over the period of 2006–2012, utilizing a specially compiled database of Eurostat information and applying Data Envelopment Analysis (DEA) to evaluate relative efficiency. Bortoletto and Favaro (2019) corroborated findings from prior studies using conventional measures but also introduced novel output measures, uncovering a widespread decrease in healthcare efficiency in numerous European nations as a consequence of the economic crisis. Similar Data Envelopment Analysis approaches were applied in studies by Kriksciuniene and Sakalauskas (2017), Kocisova et al. (2019), and Izadikhah (2022) within the scope of analysis of the performance of the healthcare system. Kocisova et al. (2019) and Stefko et al. (2018) investigated the efficiency of healthcare utilizing Data Envelopment Analysis (DEA) by analyzing two inputs (number of beds and medical staff) and two outputs (bed utilization and average nursing time) in an output-oriented four-year window DEA model. Kocisova et al. (2019) explored how public and private healthcare spending, educational attainment, demographic trends, wage expenses, and income disparity impact the operational efficiency of healthcare. Guo et al. (2022) assessed the efficiency of China's unified healthcare across various regions between 2009 and 2019, utilizing a combination of the non-radial directional distance function and the meta-frontier method to analyze both static and dynamic changes in efficiency, taking into account regional differences and non-radial adjustments. The findings indicated higher efficiency in healthcare within eastern China compared to other regions, with a notable peak in efficiency for all regions in 2012 and an overall annual improvement in efficiency of 2.68 % throughout the study period (Guo et al., 2022). Li et al. (2023) analyzed healthcare efficiency and its impact on the equitable access to healthcare and the uniformity of healthcare development across different regions. Through stochastic frontier analysis, they constructed a comprehensive model to assess healthcare efficiency on a regional basis and investigated the factors influencing this efficiency. Focusing on China as a case study, the research uncovered pronounced disparities in healthcare efficiency, with economic, social, and locational factors playing crucial roles, and highlighted the divergent effects of population density on efficiency, proposing targeted policy measures to boost regional healthcare efficiency.

Zhou et al. (2021) examined health expenditure efficiency and its influences within emerging economies, classified by income levels, drawing on the World Bank's World Development Indicators for 21 countries from 2000–2018. Efficiency scores were calculated in the first phase of analysis, with the second phase identifying health efficiency determinants through Tobit regression analysis, further validated by Simar–Wilson regression tests. The findings of Zhou et al. (2021) highlighted the positive role of research and development (R&D) and physician availability in improving health efficiency across different income groups, while corruption has a negative impact and education has inconsistent effects, emphasizing the critical role of health research in policymaking for emerging economies. Paraschi (2023) assessed the performance of national healthcare systems in various southeastern European nations, analyzing their efficiency before and after the outbreak of the COVID-19 pandemic through a two-stage data envelopment analysis (DEA). Inputs such as healthcare spending and workforce were examined alongside vaccination rates and outcomes such as life expectancy, with a subsequent analysis linking DEA outcomes to socioeconomic indicators including GDP and the Gini coefficient. Paraschi (2023) uncovered differing efficiency levels across countries, highlighting improvements and the impact of socioeconomic factors on national healthcare system performance. Sinimole (2023) examined how health systems globally have managed the intense demands triggered by the viral pandemic, highlighting the complexity of strengthening these systems beyond merely augmenting resources. Through the application of data envelopment analysis (DEA), they assessed the efficiency of worldwide health systems, organizing countries into four distinct clusters according to their infection rates and constructing models to measure health system efficiency within each group. Sinimole (2023) identified 16 countries as exhibiting relative efficiency in their health system responses, drawing attention to the successful strategies employed by these nations.

The results of analysis showed a common tendency to apply Data Envelopment Analysis (DEA) to measure healthcare efficiency in different contexts, ranging from individual countries such as China to broader regional assessments in Europe and globally. Studies (Liu et al., 2012; Bortoletto and Favaro, 2019; Kriksciuniene and Sakalauskas, 2017; Kocisova et al., 2019; Izadikhah, 2022; Stefko et al., 2018) have utilized DEA to compare government healthcare spending, out-of-pocket expenses, and the impact of socioeconomic factors on healthcare efficiency, consistently finding disparities in efficiency levels and the significant influence of economic, social, and demographic factors. However, these analyses, while insightful, do not fully account for the desirable and undesirable outputs simultaneously, indicating a methodological limitation of DEA in this context. This gap underscores the necessity of adopting more nuanced methods such as the Malmquist Productivity Index, as suggested by some studies (Chowdhury et al., 2011; Masri and Asbu, 2018; Liu et al., 2019; Guo et al., 2022; Zhou et al., 2023a; Ibrahim, 2023), for a more comprehensive assessment that captures both positive and negative outputs of healthcare efficiency, offering a clearer understanding of healthcare system performance and areas for policy intervention.

2.2. The Impact of Digital Public Services on Healthcare Efficiency

Studies (Ranerup et al., 2013; Sharaf and Shilbayeh, 2019; Ranerup and Henriksen, 2019) have shown that digital technologies improve healthcare efficiency. Thus, Ranerup and Henriksen (2019) explored the impact of informational support on citizens' ability to select a primary healthcare provider in Sweden, based on a survey of 990 people, within the framework of public healthcare choice reforms. They applied the Callon and Muniesa model to understand how technology aids in the decision-making process, revealing a preference for public healthcare portals and specific information such as waiting times and professional qualifications. Rodrigues et al. (2003) outlined that e-health has evolved in advanced countries, moving beyond offering online health information to adopting e-commerce practices for health administration and clinical support. This technological approach is increasingly seen as vital to the efficiency of modern, decentralized healthcare models across the globe. Originally developed for major organizations in industrialized settings, e-health technologies are now being considered solutions for healthcare challenges in developing countries, underscoring the necessity of analyzing successes and failures in e-health from developed nations to guide strategic implementation in less developed contexts. Sideridis et al. (2022) underscored the critical need for systems that facilitate cross-border exchanges in healthcare, social services, and environmental protection to enhance mobility within the EU, detailing the design considerations for a service that integrates healthcare facilities across nations. Utilizing healthcare systems in Greece and the UK as examples, Sideridis et al. (2022) assessed the viability and desirability of a unified EU-wide smart health service, following the outlined conceptual framework. Abbas et al. (2022) applied the GMM model to confirm that digital public services (measured by the E-Government Development Index, EGDI) significantly enhance healthcare efficiency by streamlining administrative processes, improving access to care, and facilitating real-time data exchange among healthcare providers. This transformation leads to better patient outcomes, reduced healthcare costs, and a more responsive and integrated healthcare system. Alazzam et al. (2018) proved that mobile health applications (as a tool of digital public services) improve hospital service quality and decrease healthcare expenses. Concentrating on hospitals in Jordan, Alazzam et al. (2018) employed questionnaires to collect information, highlighting that factors such as knowledge, awareness, and trust play crucial roles in the adoption and usage of mobile health applications by medical staff, as demonstrated by the analysis of 278 responses out of 555 distributed surveys. Anthopoulos et al. (2016) examined the prevalent reasons behind the failure of electronic government (e-government) projects, including gaps between design and reality, poor project management, and unrealistic expectations, highlighting the U.S. Healthcare.gov website as a case study to analyze the disconnect between political objectives and project execution. Anthopoulos et al. (2016) demonstrated how public backlash and the attention of influential opinion leaders on social media impact e-government initiatives, proposing a framework for categorizing the causes of e-government project failures and initiating a classification for the reaction of social media users to these failures. Elder (2015) outlined the difficulties encountered during the rollout of the HealthCare.gov website in the U.S., scrutinizing the sociopolitical dynamics and administrative shortcomings that contributed to its problematic launch. Elder (2015) explored the discrepancy between political intentions and practical execution, examining the public's and opinion leaders' reactions on social media to understand e-government project mishaps and suggesting a classification for social media backlash against these failures. Utilizing SmartPLS path analysis with data from Bureau of National Health Insurance users' feedback, Chen et al. (2022) underscored the critical role of healthcare organizations in developing superior IT platforms to improve service and sustain customer loyalty. Upadhyay et al. (2023) outlined factors influencing the acceptance of e-government telemedicine services by expanding the unified model of e-government adoption to include variables such as perceived severity, self-efficacy, and political trust, based on feedback from 452 Indian respondents. Upadhyay et al. (2023) outlined that attributes such as performance expectancy, perceived severity, effort expectancy, perceived risk, and political trust are crucial in shaping Indian consumers' attitudes towards EGTMS, with political trust additionally affecting social influence, though social influence itself did not show a significant effect. As a groundbreaking investigation into the behavioral intentions of Indian healthcare consumers towards e-government telemedicine services. Hedström et al. (2016) investigated the challenges of implementing electronic identification (eID) cards in healthcare settings through a case study approach, highlighting the importance of understanding eID cards as sociotechnical artifacts that intersect various social worlds. Hedström et al. (2023) identified key issues such as usability, user behavior, and privacy, which are interpreted differently across different social groups. Hedström et al. (2023) emphasized the need for a sociotechnical perspective to address these challenges effectively, contributing to the broader discourse on identity management in healthcare. Kassen (2023) investigated the deployment of digital campaigns by governments worldwide to inform the public about COVID-19, with the aim of increasing awareness and disseminating preventive measures. Kassen (2023) confirmed the need to implement diverse strategies for public engagement, data handling, and digital solution utilization adopted by healthcare policymakers, influenced by directives from both higher governmental echelons and civil society inputs. Kovac (2014) suggested that successful e-health strategies could provide a template for wider e-government projects, referring to conversations with officials from the European Commission about advancements in e-health across Europe and detailing the challenges to be overcome, the impact of EU data protection policies, and initiatives aimed at fostering entrepreneurship and employment growth in the health sector, supported by supplementary web content. Pors (2018) explored the dynamics between digital services and healthcare efficiency, with a specific look at how electronic patient records and IT-enabled self--reporting by pregnant women reshape the interaction between healthcare providers and patients. Through a grounded theory approach, based on interviews and observations at an antenatal care facility, it examines the redistribution of tasks and the transformation of relationships in healthcare due to digitalization. The research delineates four unique forms of patient engagement that emerge from the use of digital technologies, offering a nuanced view of how digitization affects healthcare delivery and challenging common narratives around e-government and patient-centric healthcare solutions. Seddon and Currie (2017) explored the financial aspects of healthcare, viewing the trade of healthcare products and services through a financial lens, and applied multivariate statistical techniques to conduct a comparative analysis among countries based on ICT infrastructure (in terms of both access and availability) and the utilization and sharing of health data. The research categorizes countries into three groups: frontrunners, followers, and laggards, according to their performance on quantitative metrics, revealing the diverse challenges and conditions of their healthcare systems. The results of research by Seddon and Currie (2017) indicate that improvements in ICT infrastructure and e-health practices could help reduce health disparities, but these measures alone may not fully address the deeper socioeconomic and political issues affecting healthcare systems.

The synthesis of existing research underscores the significant impact of digital technologies on healthcare efficiency, with investigations covering a range of topics from e-government telemedicine services in India to the progression of e-health in advanced nations and the establishment of cross-border healthcare systems within the EU. Yet, there remains a discernible research gap in fully comprehending the effects of key digital enablers, digital public services for businesses and citizens, on healthcare efficiency across EU countries. This gap signals the need for in-depth analysis to determine how these digital services can be effectively leveraged to bolster healthcare systems. It highlights the importance of conducting empirical research to understand the strategic deployment of digital services in improving healthcare efficiency, considering the learnings from both successful and challenging integrations of digital innovations within healthcare frameworks.

3. Materials and Methods

3.1. Data Selection, Source, and Measurement

3.1.1. Healthcare Efficiency

The primary objective of evaluating healthcare performance is to identify and enhance underperforming systems, thereby enabling them to function more effectively in the future. A critical challenge in this process is the ability to accurately gauge a system's progress or decline over various time periods. In the realm of healthcare, where dynamics are constantly evolving, this aspect of measurement is particularly vital. A significant complication in performance measurement arises from the relative nature of efficiency estimation in Data Envelopment Analysis (DEA). In DEA, the efficiency of a healthcare system is assessed in comparison to a set of peers or 'best practice' frontiers (Nistor et al., 2017; Önen & Sayın, 2018; Dincă et al., 2020). However, this relative assessment can mask absolute inefficiencies; a system might show improvement over time yet still operate below its potential efficiency. For instance, a country might improve its healthcare indicators, such as reducing average hospital wait times or enhancing overall patient satisfaction levels. However, when these achievements are compared to those of the leading countries in healthcare efficiency, it might become evident that the country still falls short in terms of optimal performance. Despite making progress, it may not yet reach the efficiency standards set by the top-performing nations in the healthcare sector.

To surmount this issue and enable a more nuanced comparison of efficiency changes across different timeframes, the Malmquist Productivity Index (MPI) is an invaluable tool (Oh and Lee, 2010; Oh, 2010; Yang and Soltani, 2021). The MPI extends beyond the snapshot evaluations of DEA, offering a dynamic analysis of productivity changes over time. It accomplishes this by decomposing these changes into two distinct components:

$$MPI = ECH \times TCH \quad (1)$$

where *ECH* measures whether a healthcare system is moving closer to or further from the best practice frontier, reflecting internal improvements or deteriorations in performance relative to previous periods; and *TCH* captures shifts in the best practice frontier itself, indicative of industry-wide advancements or regressions in healthcare technologies and practices.

By integrating MPI into the assessment process, it becomes possible to discern not only whether a healthcare system is improving in isolation, but also how it is evolving in the context of broader technological and operational advancements in the healthcare sector. This approach provides a more holistic and accurate picture of a system's performance over time, highlighting areas for targeted improvement and investment. Furthermore, it facilitates a deeper understanding of how internal efficiencies and external innovations collectively influence the overall effectiveness of healthcare delivery.

The Malmquist Productivity Index (MPI) is a method that evaluates productivity by contrasting outputs with input factors (Asghar et al., 2019; Ozbugday et al., 2020; Aydin, 2022). In the context of healthcare, as informed by a literature review on health system performance, the chosen input measures are the total health expenditure (% of GDP), total fertility rate (births per woman), and the number of people using safely managed sanitation services (% of the population). Total health expenditure (% of GDP) offers a macroeconomic perspective on the investment in healthcare relative to the country's economic size, encompassing both public and private spending. The fertility rate (births per woman) directly influences the spectrum and demand for healthcare services, particularly in maternal and child health, which in turn affects the workload and resource allocation within the healthcare system. Meanwhile, the percentage of the population using safely managed sanitation services reflects the foundational public health infrastructure, an essential element that underpins the general health of the population and the preventative aspect of healthcare. For the assessment of desirable outputs, healthy life years in absolute value at birth (year) was selected. This is a comprehensive output indicator reflecting the overall effectiveness of the healthcare system in delivering not just life-saving interventions but also in ensuring quality of life and well-being. In contrast, the chosen undesirable output is the mortality rate. High mortality rates can indicate inefficiencies in the healthcare system, such as poor access to care, low-quality services, or ineffective public health policies. In the MPI, this undesirable output is essential for assessing whether health systems are successful in achieving the most fundamental goal of healthcare: keeping the population alive and reducing the rates of death from preventable causes. Therefore, healthcare efficiency in a country can be represented by formula (2):

$$Health^{G} = \langle (y, \quad b, \quad x| \quad x can\ produce(y, \quad b) \quad \rangle \tag{2}$$

where x represents the input parameters; y is a desirable output of the healthcare system; and b is an undesirable output.

Healthcare efficiency, according to formulas (1) and (2), can be expressed mathematically as a function of the inputs and outputs used in the healthcare system:

$$Health_{I}^{t+1} = \sqrt{\frac{D_{I}^{t}\left(x^{t+1}, y^{t+1}, \quad b^{t+1}\right) * D_{I}^{t+1}\left(x^{t+1}, y^{t+1}, \quad b^{t+1}\right)}{D_{I}^{t}(x^{t}, y^{t}, \quad b^{t}) * D_{I}^{t+1}(x^{t}, y^{t}, \quad b^{t})}} \tag{3}$$

where $Health_{I}^{t+1}$ is a value of the healthcare efficiency of the countries.

The decomposition of $Health_{I}^{t+1}$ can be presented as:

$$ECH = \frac{D_{I}^{t+1}(x^{t+1}, y^{t+1}, \quad b^{t+1})}{D_{I}^{t}(x^{t}, y^{t}, \quad b^{t})} \tag{4}$$

$$TCH = \sqrt{\frac{D_{I}^{t}\left(x^{t+1}, y^{t+1}, \quad b^{t+1}\right) * D_{I}^{t}(x^{t}, y^{t}, \quad b^{t})}{D_{I}^{t+1}(x^{t+1}, y^{t+1}, \quad b^{t+1}) * D_{I}^{t+1}(x^{t}, y^{t}, \quad b^{t})}} \tag{5}$$

The data for EU countries spanning from 2014 to 2022, concerning both input and output variables for healthcare efficiency, was sourced from the World Health Organization's Global Health Observatory (2023), Eurostat (2023), and the World Bank (2023) database. This study applies Stata 18SE for analysis.

3.1.2. Digital Public Services

Digital public services can streamline processes, reduce the administrative burden, and enhance accessibility, all of which are critical components of an efficient healthcare system. Based on the literature (Krotel, 2021; Ding et al., 2021; Ha, 2022; Thanh, 2022; Pan et al., 2022), digital public services for businesses and digital public services for citizens were chosen as indicators for exploring the role of digital transformation in healthcare efficiency. Digital public services for businesses (eGovbuss) represent the degree to which services or information relevant to businesses are provided online, typically through a dedicated portal. In the context of healthcare efficiency, this variable captures the effectiveness of digital interfaces in facilitating business-related healthcare activities, such as pharmaceutical companies' interactions, medical equipment procurement, and digital services for healthcare providers. A high eGovbuss score indicates a robust digital infrastructure that can streamline administrative processes, reduce costs, and increase the overall efficiency of the healthcare system from a business standpoint. Digital public services for citizens (eGovcit) measure the extent to which public services and information aimed at citizens are made available online, including through portals. In terms of healthcare efficiency, eGovcit reflects how effectively a healthcare system engages with patients and the public via digital means. This includes online appointment scheduling, telemedicine services, electronic health records, and public health information dissemination. A sophisticated eGovcit infrastructure leads to improved patient access to services, better health outcomes, and increased overall efficiency of the healthcare system.

3.2. Model Construction

3.2.1. Tobit Model

Healthcare efficiency scores are subject to censoring since the index values are bound by a threshold—specifically, if the index exceeds 1, it indicates an increase in productivity between the time points t and $t+1$. This bounded nature of the efficiency scores presents a complication for standard linear regression models, which presuppose error normality and cannot adequately handle limited-range dependent variables. The Tobit model accommodates the peculiarities of censored dependent variables by considering both their upper and lower limits (Shuai and Fan, 2020; Amore and Murtinu, 2021; Cao et al., 2022). It is thus an appropriate analytical tool for efficiency scores derived from the Malmquist Productivity Index, capable of integrating both censored and uncensored observations into the analysis. Consequently, the Tobit model is employed for regression analysis to provide a more accurate estimation in the presence of censored data:

$$\upsilon_{ij}^{*} = \beta\gamma_{ij} + a_{ij} + \varepsilon_{ij}, \varepsilon_{ij} \sim N(0, \sigma^{2}), \quad \upsilon_{ij} = \begin{cases} \upsilon_{ij}^{*}, 0 \le \upsilon_{ij}^{*} \le 1 \\ 0, \upsilon_{ij}^{*} < 0 \\ 1, \upsilon_{ij}^{*} > 1 \end{cases} \tag{6}$$

where υ_{ij}^{*} – the explained variable, γ_{ij} – the independent variable, and ε_{ij} – the error term.

3.2.2. Variable selection

Explained variable. Healthcare efficiency, as quantified by the Malmquist Productivity Index, was selected as the dependent variable for the regression model (6). To facilitate analysis using the Tobit regression model, which is suitable for censored data, the $Health_{I}^{t+1}$ scores were inverted to represent healthcare inefficiency scores:

$$\text{Transformed\_}Health_{I}^{t+1} = \frac{1}{Health_{I}^{t+1}} - 1 \tag{7}$$

In the context of the model (6), a negative regression coefficient suggests an association with higher efficiency, while a positive coefficient indicates a correlation with greater inefficiency. This inverse relationship is essential for interpreting the Tobit model's outputs correctly.

Explanatory variables: in model (6), the indicators *eGovbuss* and *eGovcit* were utilized separately as explanatory variables. Including both indicators simultaneously in the model could lead to issues of multicollinearity.

Control variables. Urbanization level (*Urban*). Urbanization significantly influences healthcare needs and service delivery (Tripathi and Maiti, 2023; Rahaman et al., 2023; Li et al., 2023). Urban areas often have better access to healthcare facilities and digital infrastructure, which can affect the efficiency of digital public services in healthcare. Trade openness (*TO*). The degree of a country's openness to trade can be an indicator of its economic integration and technological advancement, which in turn can impact healthcare efficiency (Szczepańska-Woszczyna et al., 2022; Lyulyov et al., 2023). Countries with higher trade openness might have better access to medical technologies and innovations, thus potentially enhancing the effectiveness of digital public services in healthcare. CO2 emissions, metric tons per capita (*CO2*). CO2 emissions per capita can be an indirect indicator of a country's industrialization level and its environmental policies (Dzwigol et al., 2021), which can have significant health implications. Higher emission levels could correlate with poorer air quality and higher incidence of respiratory diseases, thus affecting the healthcare system's load and efficiency.

The Variance Inflation Factor (VIF) was utilized to detect multicollinearity. VIF values exceeding 5 or 10 are indicative of potential issues. The descriptive statistics of the chosen variables are presented in Table 1.

Considering the results (Table 1), the average healthcare expenditure is noted at 8.528 % of GDP with a variability indicating a range from 4.9 % to 12.9 %, suggesting diverse investment levels across countries. Fertility rates show less variation, averaging 1.535 children per woman, with extremes from 1.061 to 2 children. Access to safely managed sanitation services is relatively high on average (87.790 %) but varies from 64.741 % to 99.672 %, reflecting disparities in infrastructure. Mortality rates and healthy life expectancy data reveal significant health outcome differences among populations, with mortality rates averaging 932.317 per 100,000 people and healthy life expectancy at 62.013 years. Digital government services for businesses and citizens (eGovbuss

Table 1
Summary statistics of chosen variables.

Variable	Source	Mean	SD	Min	Max
Health expenditure	World Health Organization's Global Health Observatory (2023)	8.528	1.919	4.900	12.900
Fertility rate		1.535	0.180	1.061	2.000
People using safely managed sanitation services		87.790	7.923	64.741	99.672
Mortality rate		932.317	196.258	651.800	1667.100
Healthy life		62.013	4.899	51.400	73.600
eGovbuss	Eurostat (2023)	68.393	18.087	18.000	112.536
eGovcit		51.961	20.255	13.250	104.071
Urban	World Bank (2023)	73.334	13.324	52.162	111.128
TO		136.524	71.019	55.266	393.141
CO2	Eurostat (2023)	6.638	2.880	2.461	20.134

and eGovcit) show average scores of 68.393 and 51.961, respectively, with wide ranges indicating varying degrees of digital integration. Urbanization rates average 73.334 %, yet span from moderately urban to highly urban, indicating diverse living environments. Technical output and CO2 emissions metrics further highlight the disparity in productivity and environmental impact, with technical output averaging at 136.524 and CO2 emissions at 6.638 metric tons per capita.

4. Results

The fluctuations shown in the empirical findings (Fig. 1) signify that the Malmquist Productivity Index for healthcare efficiency does not adhere to a consistent pattern of growth or decline, but varies annually due to a myriad of factors.

A value of the Malmquist Productivity Index for healthcare efficiency greater than one indicates an improvement in productivity, signifying that a country has enhanced its efficiency in transforming inputs into outputs. Conversely, a value of less than one suggests a decline in productivity, pointing to reduced efficiency. Values close to one indicate stability in healthcare efficiency. Austria, Belgium, and Bulgaria exhibit these fluctuations vividly, with Austria and Belgium experiencing notable growth in 2017 and 2020, respectively, but also facing declines in others. Bulgaria shows a general upward trend, peaking in 2021, but then sharply dropping in 2022. This pattern was echoed to varying degrees in Lithuania in 2020 and Finland in 2021, showcasing significant productivity leaps, potentially indicating the successful implementation of economic policies or investments in technology. On the other hand, sharp declines in countries such as Romania in 2022 and Spain in 2021 may reflect economic challenges or inefficiencies encountered during those times. The diverse trends across these countries highlight the complex interplay of factors influencing the Malmquist Productivity Index for healthcare efficiency. They underscore the critical role of adaptive economic policies and the need for continuous innovation and efficient management practices to foster sustainable growth and improve healthcare.

Table 2 displays the mean values and standard deviations (SD) for the Health Score, along with its two constituent components: ECH (Efficiency Change) and TCH (Technological Change). In the analysis of productivity changes over the period from 2014 to 2022, any value of the index or its components (ECH and TCH) below one indicates a regression in the productivity of the Decision Making Unit (DMU) during this time frame. Conversely, values above one signify an improvement in productivity. A value exactly equal to one indicates that there has been no significant change in productivity, suggesting stagnation.

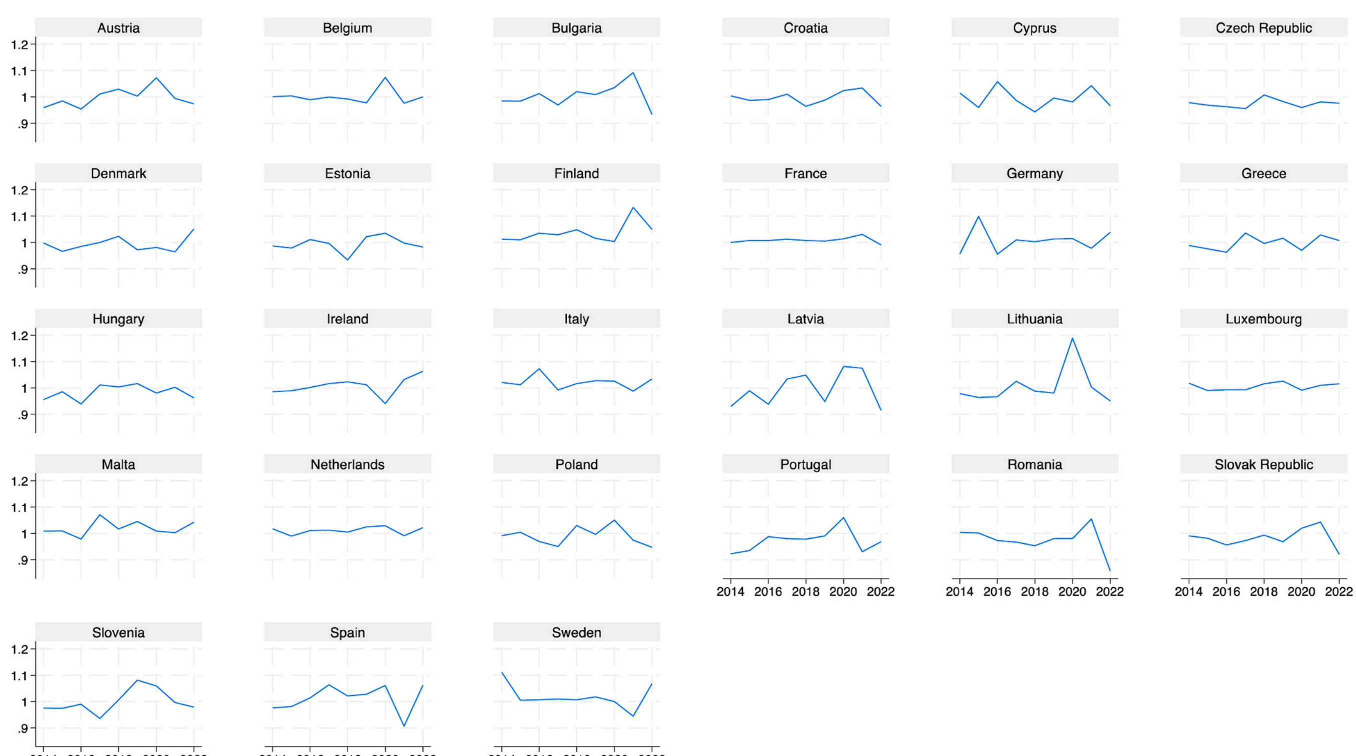

Figure 1. The results of the Malmquist Productivity Index for healthcare efficiency among EU countries for 2014–2022.

Table 2
Summary of the Healthcare Efficiency Index by country (mean, standard deviation).

Country	Indicator	Mean	SD	Country	Indicator	Mean	SD
Austria	*Health*	0.998	0.037	Italy	*Health*	1.021	0.025
	ECH	0.988	0.038		*ECH*	1.012	0.028
	TCH	1.011	0.012		*TCH*	1.009	0.008
Belgium	*Health*	1.002	0.029	Latvia	*Health*	0.996	0.066
	ECH	0.994	0.031		*ECH*	0.984	0.059
	TCH	1.007	0.006		*TCH*	1.012	0.036
Bulgaria	*Health*	1.005	0.045	Lithuania	*Health*	1.005	0.072
	ECH	0.993	0.029		*ECH*	0.997	0.076
	TCH	1.012	0.030		*TCH*	1.009	0.025
Croatia	*Health*	0.996	0.024	Luxembourg	*Health*	1.006	0.014
	ECH	0.993	0.023		*ECH*	1.000	0.009
	TCH	1.003	0.004		*TCH*	1.006	0.008
Cyprus	*Health*	0.994	0.038	Malta	*Health*	1.021	0.028
	ECH	0.989	0.036		*ECH*	1.000	0.011
	TCH	1.005	0.006		*TCH*	1.020	0.020
Czech Republic	*Health*	0.975	0.016	Netherlands	*Health*	1.012	0.014
	ECH	0.974	0.015		*ECH*	1.002	0.015
	TCH	1.001	0.002		*TCH*	1.009	0.008
Denmark	*Health*	0.993	0.029	Poland	*Health*	0.991	0.035
	ECH	0.989	0.028		*ECH*	0.989	0.035
	TCH	1.004	0.005		*TCH*	1.001	0.002
Estonia	*Health*	0.994	0.029	Portugal	*Health*	0.973	0.042
	ECH	0.993	0.029		*ECH*	0.964	0.043
	TCH	1.001	0.001		*TCH*	1.009	0.011
Finland	*Health*	1.037	0.040	Romania	*Health*	0.975	0.053
	ECH	1.023	0.040		*ECH*	0.974	0.051
	TCH	1.014	0.012		*TCH*	1.001	0.002
France	*Health*	1.008	0.011	Slovak Republic	*Health*	0.983	0.036
	ECH	1.006	0.013		*ECH*	0.980	0.032
	TCH	1.002	0.003		*TCH*	1.003	0.006
Germany	*Health*	1.007	0.044	Slovenia	*Health*	1.000	0.045
	ECH	0.998	0.044		*ECH*	0.997	0.046
	TCH	1.009	0.012		*TCH*	1.003	0.002
Greece	*Health*	0.998	0.026	Spain	*Health*	1.013	0.052
	ECH	0.990	0.019		*ECH*	0.995	0.046
	TCH	1.008	0.009		*TCH*	1.018	0.019
Hungary	*Health*	0.984	0.027	Sweden	*Health*	1.019	0.047
	ECH	0.984	0.027		*ECH*	1.013	0.045
	TCH	1.001	0.001		*TCH*	1.006	0.005
Ireland	*Health*	1.007	0.034				
	ECH	1.007	0.034				
	TCH	1.000	0.000				

Austria exhibits a slight decline in overall healthcare efficiency with a health index mean of 0.998. While its ECH (0.988) indicates a decrease in efficiency relative to the best practice frontier, the TCH (1.011) suggests some technological advancement. Italy shows an improvement in healthcare efficiency with a health index mean of 1.021. Its ECH of 1.012 implies increased efficiency, and a TCH of 1.009 indicates technological progress, albeit modest. Both Belgium and Bulgaria, have a health index mean slightly above one (Belgium at 1.002 and Bulgaria at 1.005), suggesting marginal improvements in overall healthcare efficiency. However, Belgium's lower ECH score (0.994) compared to Bulgaria's (0.993) indicates slightly less improvement in efficiency relative to the best practice frontier. Cyprus reflects a minor decline in healthcare efficiency with a health index mean of 0.994. The ECH score of 0.989 and a TCH score of 1.005 suggest that while there is a decline in efficiency, there is also a slight improvement in technology. The Czech Republic shows a notable decline in healthcare efficiency with a health index mean of 0.975, one of the lower scores. Both its ECH (0.974) and TCH (1.001) are lower, indicating a decrease in efficiency and negligible technological change. Finland stands out with a significant improvement in healthcare efficiency, with a health index mean of 1.037. Both its ECH (1.023) and TCH (1.014) are high, suggesting notable improvements in efficiency and technology. Portugal exhibits a more pronounced decline with a health index mean of 0.973. Its ECH score of 0.964 is particularly low, indicating a significant decrease in efficiency, although this is slightly offset by a modest increase in technology (TCH of 1.009). Spain and Sweden show improvement in healthcare efficiency (Spain with a mean of 1.013 and Sweden with 1.019). Spain's higher TCH score (1.018) compared to Sweden's (1.006) suggests more substantial technological advancement.

The results (Table 3) allow us to outline the duration of growth, stagnation, or decline in the Health Change Index for analyzed countries. Categorized based on the number of years each country experienced significant changes in its Health Change Index, they are divided into three groups: those with consistent growth (>1 year of positive

Table 3
The duration of growth, stagnation, or decline in the Health Change Index.

Country	Number of years			Country	Number of years		
	>1	=1	>1		>1	=1	>1
Austria	4	0	5	Italy	7	0	2
Belgium	4	0	5	Latvia	4	0	5
Bulgaria	5	0	4	Lithuania	3	0	6
Croatia	4	0	5	Luxembourg	5	0	4
Cyprus	3	0	6	Malta	8	0	1
Czech Republic	1	0	8	Netherlands	7	0	2
Denmark	2	0	7	Poland	3	0	6
Estonia	3	0	6	Portugal	1	0	8
Finland	9	0	0	Romania	3	0	6
France	7	0	2	Slovak Republic	2	0	7
Germany	6	0	3	Slovenia	3	0	6
Greece	4	0	5	Spain	6	0	3
Hungary	4	0	5	Sweden	7	0	2
Ireland	6	0	3				

change), periods of stagnation (=1 year of change), or declines in health indicators (>1 year of negative change).

The findings show that Finland and Portugal lead the way with nine and eight years of continuous health improvement, respectively. Conversely, Denmark, the Netherlands, and Sweden have seen prolonged stagnation, with seven years each of no significant change. Mixed patterns are evident in Italy and France, with varying trends of growth and stagnation. These trends hold economic significance, as persistent growth suggests effective healthcare policies and investments, while stagnation or decline may necessitate policy adjustments to revitalize healthcare systems and mitigate economic impacts such as increased healthcare spending or reduced workforce productivity.

The VIF analysis in Table 4 reveals low multicollinearity among the model's independent variables, with eGovcit showing VIF values of 1.22 and 1.21, and CO2 at 1.03. Similarly, TO and Urban have VIFs of 1.01 and 1.03, respectively. These results, all close to 1, indicate minimal multicollinearity, ensuring that each variable distinctly contributes to the model without concerns of bias.

In terms of the transformation $Health_I^{t+1}$ scores, in the Tobit model a negative regression coefficient implies an association with higher efficiency, whereas a positive coefficient indicates a correlation with greater inefficiency. Thus, the results (Table 5) indicate that there is a statistically significant positive impact of e-government business sophistication (eGovbuss) on health efficiency in Model 1. The coefficient of −0.00041 suggests that for each unit increase in eGovbuss, there is an associated growth of 0.00041 units in health efficiency, holding all other factors constant. This negative coefficient implies that as countries improve their e-government business sophistication, their health efficiency tends to increase.

The results for Model 2 show that the coefficient of −0.00036 for e-government business sophistication suggests that improvements in this area are linked with higher efficiency of healthcare, indicating that countries enhancing their e-government practices tend to operate more efficiently in healthcare policy. Urbanization, represented by a coefficient of −0.00038, also exhibits an inverse relationship with efficiency, implying that increased urbanization could lead to higher healthcare efficiency levels. Moreover, the coefficient of 0.00067 for trade openness suggests that while it may bring economic benefits, it could also result in inefficiencies. However, the impact of carbon dioxide emissions on healthcare efficiency is inconclusive due to the coefficient's lack of statistical significance. The findings in Model 3 make it possible to suggest that an increase in e-government is associated with higher healthcare efficiency. This implies that as countries enhance their e-government practices from the perspective of citizen engagement and services, they tend to operate more efficiently in terms of delivering public services and managing administrative processes. The empirical results for Model 4 show that urbanization has a negative coefficient, suggesting that increased urbanization is associated with higher efficiency. However, trade openness has a positive coefficient of 0.00062, indicating a correlation with greater inefficiency of healthcare. Carbon dioxide emissions show a negative but insignificant coefficient of −0.00034. The indicator eGovcit has a negative coefficient, suggesting that improving digital public policy for citizens leads to growth in healthcare efficiency by 0.00025.

The robustness test results (Table 6), after excluding countries with the highest $Health_I^{t+1}$ scores (Finland, Spain, and Sweden), reveal that for Model 1, the coefficient for eGovcit is −0.00029 with a standard error of 0.00013, indicated as statistically significant at the $p < 0.05$ level. Model 2 shows a coefficient for eGovbuss of −0.00037 with a standard error of 0.00013, marked with a higher level of statistical significance at $p < 0.01$. The findings in Table 6 are coherent to the empirical results in Table 5.

Table 7 presents the results of the robustness test that incorporates the control variable of good governance (WGI). This variable includes key aspects such as political stability, government effectiveness, regulatory quality, rule of law, and control of corruption, all of which can profoundly impact a country's healthcare efficiency. Effective governance is associated with enhanced resource allocation, improved healthcare policies, and a more effective implementation of digital

Table 4
The empirical outputs of VIF.

VIF	Variable				
	eGovcit	**eGovcit**	**CO2**	**TO**	**Urban**
	–	1.22	1.03	1.01	1.22
	1.21	–	1.03	1.03	1.21

Table 5
The findings of the Tobit model.

Variables	(1)	(2)	(3)	(4)
	Model 1	**Model 2**	**Model 3**	**Model 4**
eGovbuss	-0.00041***	-0.00036**		
	(0.00014)	(0.00016)		
Urban		-0.00038*		-0.00042**
		(0.00021)		(0.00021)
TO		0.00067**		0.00062**
		(0.00030)		(0.00030)
CO2		0.00018		-0.00034
		(0.00492)		(0.00495)
eGovcit			-0.00036***	-0.00025*
			(0.00012)	(0.00014)
Constant	0.02909***	0.05096***	0.01967***	0.04215***
	(0.00961)	(0.01527)	(0.00676)	(0.01460)
Observations	243	216	243	216

Note: Standard errors in parentheses.
*** $p<0.01$.
** $p<0.05$.
* $p<0.1$.

Table 6
The findings of robustness test (excluding Finland, Spain, and Sweden).

Variables	(1)	(2)
	Model 1	**Model 2**
eGovcit	-0.00029**	
	(0.00013)	
eGovbuss		-0.00037***
		(0.00013)
Constant	0.01850***	0.02856***
	(0.00687)	(0.00941)
Observations	216	216

Note: Standard errors in parentheses.
** $p<0.05$.
*** $p<0.01$.

Table 7
The findings of the robustness test with the addition of the control variable WGI.

Variables	(1)	(2)
	Model 1	**Model 2**
eGovcit	-0.00034***	
	(0.00013)	
WGI	-0.06307*	-0.06442*
	(0.03393)	(0.03380)
eGovbuss		-0.00043***
		(0.00015)
Constant	0.01845**	0.03049***
	(0.00746)	(0.01055)
Observations	216	216

Note: Standard errors in parentheses.
*** $p<0.01$.
* $p<0.1$.
** $p<0.05$.

services.

The findings revealed statistically significant negative coefficients for eGovcit (-0.00034 at the 1 % level), eGovbuss (-0.00043 at the 1 % level), and governance quality (WGI at −0.06307 and −0.06442 at the 10 % level for models 1 and 2, respectively). These results are consistent with previous calculations presented in Tables 5 and 6. They highlight the significant influence of governance quality in augmenting the effectiveness of digital public policies in healthcare.

5. Discussion

The findings of this study confirm that digital public services have an impact on healthcare efficiency. The findings from the Tobit model analysis demonstrate a statistically significant positive impact of e-government business sophistication on healthcare efficiency. This resonates with the insights of Downes et al. (2019), Chanchaichujit et al. (2019), and Akinola and Telukdarie (2023) into the transformative potential of e-government initiatives, suggesting that such digital transformations significantly improve healthcare services by enhancing access to information, streamlining administrative processes, and facilitating patient-centered care.

The inclusion of Worldwide Governance Indicators (WGI) as control variables in this study not only highlights the essential role of governance quality in boosting the effectiveness of digital public policies in healthcare but also addresses a significant research gap previously identified (Chowdhury et al., 2011; Masri and Asbu, 2018; Liu et al., 2019; Zhou et al., 2021; Paraschi, 2023; Sinimole, 2023). The findings support the notion that digitalization positively impacts healthcare efficiency, a theme consistent with earlier research (Liu et al., 2012; Sinimole, 2023). This study underscores the need for adaptive policies, high-quality governance, and ongoing innovation to fully harness the capabilities of e-government initiatives in improving healthcare systems worldwide. Moreover, this extended analysis highlights how outcomes of digital public policies could significantly across different governance environments. By comparing countries with diverse levels of governance quality, the study demonstrates that identical digital strategies lead to different outcomes depending on the local governance framework. This finding is vital for policymakers tasked with customizing digital health strategies to their specific governance contexts to optimize results. The study also points to the necessity for policies to evolve alongside technological and governance changes. As digital technologies advance, the governance frameworks that underpin their application in the healthcare sector must also be dynamic. This necessitates a forward-thinking approach to policymaking that anticipates and adapts to changes, ensuring that digital health initiatives remain effective and meet the evolving needs of the population.

In comparison to earlier investigations (Rodrigues, 2003; Chowdhury et al., 2011; Masri and Asbu, 2018; Liu et al., 2019; Ranerup and Henriksen, 2019; Sideridis et al., 2022; Abbas et al., 2022), this study advances the understanding of the intersection between digital governance and healthcare efficiency. It builds upon existing frameworks of e-government and healthcare transformation by empirically demonstrating how digitalization acts as a lever for healthcare system improvements. By situating the analysis within the EU—a region characterized by both diversity and unity in healthcare governance—the study offers a view of e-government's effects across different national contexts. This contributes to the theoretical discourse on public administration and digital transformation, suggesting a model for how technology allows for the achievement of effective and equitable healthcare delivery.

Practically, the findings of this study could be applied by policymakers, healthcare administrators, and stakeholders involved in the governance of healthcare systems. By identifying e-government as a positive determinant for healthcare transformation, the study provides a compelling case for the prioritization of digital initiatives in healthcare policy. It offers concrete evidence to support the integration of digital services in healthcare delivery, highlighting the potential for enhanced efficiency and improved patient outcomes. Moreover, the research outlines the importance of adaptive policies that embrace digital transformation as a means to address contemporary healthcare challenges. As such, this study serves as a foundational reference for future policy formulation and the strategic planning of digital healthcare initiatives, offering a roadmap for leveraging technology to meet the evolving needs of populations and enhance the sustainability of healthcare systems. This paper enriches both the theoretical and practical understanding of how digital transformation, facilitated by e-government, revolutionizes healthcare systems. It underscores the need for ongoing innovation and adaptive governance in meeting the health demands of current and future generations, marking a significant step forward in the discourse on digital governance and healthcare efficiency.

6. Conclusions

The empirical results allow us to outline that healthcare efficiency in EU countries is influenced by a complex interplay of factors, with significant implications for policy and management. The findings highlight the need for continuous adaptation and digitalization in healthcare policies and practices to improve efficiency. Based on the empirical findings and analysis of healthcare efficiency through digital public services, several policy implications could be outlined to enhance healthcare efficiency.

The diverse trends across countries underscore the importance of sustainable growth (Pudryk et al., 2023) in healthcare efficiency, which could be achieved through continuous innovation, effective management, and the adaptation of healthcare policies to changing circumstances. Germany has been a frontrunner in incorporating innovation to enhance healthcare efficiency. Germany's Digital Healthcare Act enables patients to access digital health applications reimbursed by health insurance, fostering a culture of innovation within the healthcare system. These measures aim to improve efficiency and patient outcomes through technological advancements. Sweden aims to be the world leader in e-health by 2025, focusing on improving healthcare accessibility and efficiency through digital technologies. The country's national e-health strategy includes the development of secure digital communication channels between patients and healthcare providers, electronic health records being made accessible to patients, and digital tools for self-care and treatment. These efforts are designed to streamline healthcare services, reduce administrative burdens, and improve patient engagement in their care.

The findings from the Tobit model analysis reveal the positive impact of e-government business sophistication on healthcare efficiency. Policies that promote the development and implementation of sophisticated e-government services lead to improvements in healthcare efficiency. This includes enhancing citizen engagement, optimizing administrative processes, and providing high-quality digital public services. The Netherlands has made significant strides in e-health, focusing on digital innovations to improve healthcare efficiency. Initiatives such as the Personal Health Record (PHR) system allow citizens to access and manage their health information online. Additionally, the Dutch government supports the use of mobile health apps, which facilitate remote care and patient monitoring, thereby optimizing healthcare delivery.

Improving healthcare efficiency through digital public services requires a multifaceted approach that involves innovative and adaptive policies, investments in technology, enhancements in e-government practices, careful consideration of urbanization and trade openness, quality governance, and continuous monitoring and evaluation (Gallo et al., 2019; Kadar and Reicher, 2020). These policy implications can guide governments and healthcare policymakers in developing strategies to enhance healthcare efficiency and ultimately improve health outcomes for their populations.

Despite its valuable insights, this study has several limitations that future research could address. The investigation primarily focuses on e-government business sophistication, potentially overlooking the impact of other digital initiatives on healthcare efficiency. Additionally, drawing upon studies by Kwilinski et al. (2020) and Dzwigol (2021), it is evident that healthcare efficiency and digitalization are influenced by a country's level of education and knowledge, suggesting these indicators should be included in future analyses. External factors such as technological advancements, systemic changes in healthcare, or global pandemics may influence the study's results. These factors were not explicitly addressed, which could affect the generalizability and applicability of the findings. Situated within the EU context, known for its distinctive mix of diverse and unified healthcare governance, the study's findings may not be entirely applicable to regions with markedly different healthcare systems or digital governance frameworks. Expanding the scope of research to include countries in Asia and the USA would enable a comparative analysis, providing broader insights and policy implications that consider geographical variations. Another crucial aspect is the influence of governance quality on healthcare efficiency. Particularly in developing countries, where healthcare often grapples with high corruption levels, investigating the impact of corruption on healthcare in the context of digital public services is necessary. This would help in understanding the interactions between governance, corruption, and digitalization in the healthcare sector. Additionally, the study could benefit from a more detailed discussion on potential limitations related to the methodologies employed.

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Ethical statement

Hereby, we (Aleksy Kwilinski, Katarzyna Szczepanska-Woszczyna, Oleksii Lyulyov, Tetyana Pimonenko) consciously assure that for the manuscript (Digital Public Services: Catalysts for Healthcare Efficiency) the following is fulfilled:

This material is the authors' own original work, which has not been previously published elsewhere.
The paper is not currently being considered for publication elsewhere.
The paper reflects the authors' own research and analysis in a truthful and complete manner.
The paper properly credits the meaningful contributions of co-authors and co-researchers.
The results are appropriately placed in the context of prior and existing research.
All sources used are properly disclosed (correct citation).
All authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.

We agree with the above statements and declare that this submission follows the policies of COPE.

CRediT authorship contribution statement

Katarzyna Szczepanska-Woszczyna: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Aleksy Kwilinski:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Tetyana Pimonenko:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Oleksii Lyulyov:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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