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The Power of E-Government to Accelerate Economic Growth: Panel Data Analysis on the Role of E-Government in the European Union's Economic Growth

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Abstract: Despite the international recognition of the vital role of e-government in realizing economic development, few empirical studies measured the relationship between e-government and economic growth, particularly in the European Union. Thus, this paper examines the impact of e-government on per capita GDP in the European Union countries where e-government is measured in two ways: (1) the e-government enablers, represented by the United Nations E-Government Development Index and its sub-indexes, namely, telecommunication infrastructure, human capital, online service, in addition to the e-participation index; (2) Eurostat variables which gauge the individuals actual use of e-government services through three modes, particularly, obtaining information, downloading official forms, and submitting completed official forms online, in addition to the overall interaction with governments online.

A panel dataset of the 27 European Union members and the United Kingdom from 2003 to 2022 is analyzed using cluster-robust fixed and random effects models. For robustness check and to resolve the possible endogeneity and reverse causality which could exist between e-government and per-capita

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GDP, the Arellano–Bover/Blundell–Bond model is estimated for the second dataset using the Generalized Method of Moments (GMM). The study found that per capita GDP is positively related to all of the e-government enablers included in the e-government development indicators. Furthermore, the estimates indicate that an increase in the percentage of individuals using e-government services by 10% is associated with a 0.4% to 1.6% increase in per capita GDP depending on the type of internet use and econometric estimation method, ceteris paribus.

***Key words**: Digital Governance, public value, economic development, EU*
***JEL Codes:** O47 , H11, C23*

Introduction

Digitalization and e-government have emerged as key drivers of resilience and sustainable development, particularly in the face of recent global economic challenges like the COVID-19 crisis and the Russia-Ukraine war. These technologies have played a vital role in facilitating the delivery of public services, promoting knowledge sharing, and enabling citizen participation in decision-making processes, both in normal and extraordinary circumstances. By leveraging e-participation tools such as open data, open budget processes, and electronic citizen consultations, e-government contributes to the establishment of a more accountable and efficient governance system. It enhances public value by providing convenient and accessible services, thereby improving overall satisfaction and the value experienced by the public. By promoting accountability and transparency in government operations, e-government plays a significant role in fighting corruption (Khan, Krishnan, and Dhir (2021); United Nations, 2022).

E-government also contributes to sustainable public procurement practices by utilizing information and communication technology (ICT) to improve the efficiency and effectiveness of procurement processes while considering sustainability factors. This ensures that public procurement aligns with environmental and social goals. Additionally, e-government can attract foreign direct investment (FDI) by digitizing public services and utilizing ICT for information diffusion and communication. This enhances the quality and efficiency of public services, rendering the country more appealing to prospective investors (Sadiq, 2021; United Nations, 2016).

Bridging the digital divide poses both opportunities and challenges for e-government. The existence of a digital divide can hinder the widespread adoption of e-government within a country. Nonetheless, prioritizing the implementation of e-government could accelerate the adoption of an integrated strategy that involves investing in telecommunication

infrastructure, online services, and developing human capacity to leverage digital services. By ensuring equal access to digital resources, e-government promotes a more equitable and inclusive society.

Hence, e-government plays a significant role in achieving the 2030 Sustainable Development Agenda. Specifically, the E-government plays a crucial role in achieving SDG target 16.7, which focuses on promoting "Responsive, inclusive, participatory, and representative decision-making at all levels". Additionally, e-government is instrumental in advancing Sustainable Development Goal 9 (SDG 9), which emphasizes the interdependent pillars of infrastructure, industry, and innovation (Chasek et al., 2017; United Nations, 2016).

Given the importance of e-government as a catalyst for achieving the 2030 agenda, the United Nations has developed the E-Government Development Index (EGDI) to monitor the member nations' performance in e-government (United Nations, 2023). The European Union comprises five of the top ten ranking countries in the E-Government Development Index 2022, and most of the 27 European Union members are among the top 40 ranking countries. This index focuses on the level of development of the enablers of e-government in terms of telecommunication infrastructure, human development, and the quality of e-government websites (United Nations, 2022). However, data about the actual use of the internet to interact with the government reveals disparity among the European Union countries which could range from 15% to 90% of the population (Eurostat, 2023). Therefore, the European Union has prioritized the enhancement of e-government services along four pillars, particularly, user-centricity, transparency and trust, technological enablers, and cross-border provision of e-government services (European Commission, 2022). To achieve this, investments and policies are being implemented in the four above-mentioned pillars.

With the target of delivering all essential public services online by 2030, e-government tops the European Union Digital Decade agenda. More than 26% of the budget under the EU Recovery and Resilience Facility has been allocated to digital transition (European Commission, 2022) which signifies the key role of e-government in achieving economic growth and resilience. Despite the recognition of the vital role of e-government in realizing economic development, few empirical studies have focused on measuring the relationship between e-government and economic growth, particularly in the European Union. Thus, the main aim of this study is to provide quantitative evidence concerning the impact of e-government on economic growth in the European Union countries and the UK.

The study contributes to the literature by analyzing the impact of e-government on per capita GDP in the European Union countries where e-government is represented in two ways. Firstly, the e-government enablers,

are represented by the e-government index and its sub-indexes, namely, the telecommunication infrastructure, human capital index, and online service index, in addition to the e-participation index. Secondly, variables that gauge the actual use of e-government services using data from the Eurostat annual survey of e-government activities of individuals via websites, where the variables represent three modes of individuals' use of e-government, namely, obtaining information, downloading official forms, and submitting completed official forms online, in addition to a variable representing the overall interaction with governments online. A panel dataset of the 27 European Union members and the United Kingdom from 2003 to 2022 is analyzed using cluster-robust fixed and random effects models. For a robustness check and to address the possible endogeneity and reverse causality that could exist between e-government and per-capita GDP, the Arellano–Bover/Blundell–Bond model is estimated for the second dataset using the Generalized Method of Moments (GMM). The study found that per capita GDP is positively related to all of the e-government enablers included in the United Nations E-Government Development Index. Furthermore, the estimates indicate that an increase in the percentage of individuals using e-government services by 10% is associated with a 0.4% to 1.6% increase in per capita GDP depending on the mode of internet use and the econometric estimation method.

Literature review

2Theoretical Framework

E-government can have different definitions and interpretations. One way of defining e-government is the use of information and communication technology in the internal operations of the public sector to integrate workflows, improve transaction times, and enable open information transfers to address the inefficiency caused by traditional paper-based systems. It can also refer to the use of Information and communication technology by the government to communicate with and provide services to external stakeholders, such as citizens and businesses (Khan, Krishnan, and Dhir, 2021; Rodriguez-Hevía et. al., 2020, United Nations, 2022). Thus, the definition of e-government has been extended from enhancing government services and online delivery services to a broader framework that covers the incorporation of information and communication technology to interact with citizens through open data, and digital modes of citizens' participation in decision-making (United Nations,2022).

The design and implementation of e-government have gained importance in the literature of managerial rationality, where such theories debate how best to structure an organization and its governance to maximize productivity and benefit from Information Technology(IT) at its greatest potential. New public management (NPM) and digital era governance (DEG) are two of the organizational structures the literature explores. New public management is a decentralized framework that views the population as clients in a market-based system and uses competition to enhance

productivity to perform government operations. Some arguments advocate that bureaucratic inefficiency led to NPM. The core ideas of digital era governance are digitalization, holism, and reintegration. It suggests reversing some of NPM's decentralization in the name of reintegration. The maturity models' proposed idea of vertical and horizontal integration is complemented by the reintegration and holism concepts. DEG stresses IT-centered managerial shifts that, proponents claim, would boost productivity and customer satisfaction. In addition, they anticipate that the second wave of digital era governance will usher in significantly novel developments (Afzal, 2016).

The public value theory has been widely discussed in the e-government literature. The public value theory defines public value as the expectations of interested parties and members of the public, such as voters, lawmakers, public employees, and taxpayers, about the provision of government services to citizens. Understanding how the government and public sector operate is essential for understanding the value of e-government. The idea of public value is used to confront and possibly resolve the dynamic social and political influence of digitalization on public and government institutions. This understanding of the roots of public value can be used in e-government to provide a wider range of policy objectives and a different set of standards by which it should be judged. relationships between the public and the government that are founded on trust (Mensah et al., 2022).

The Solow growth model is integral to the literature that examines the relationship between e-government and economic growth. It examines how changes in labor and technological advancements impact an economy's output level over time. (Boyko et al., 2020, Vipond et al., 2022). Several attempts have been made to incorporate the role of the government in economic growth within the Solow growth model framework. For example, Barro (1990) treated public services as a flow input in the production function. This approach recognizes that public services, such as infrastructure and education, contribute to the overall productivity of the economy. Cashin (1994) incorporated the government's capital stock into the production function. This means that the government's investment in physical capital, such as infrastructure projects, is considered as a factor influencing economic growth. Bajo-Rubio (2000) developed an augmented Solow Growth Model that included public inputs affecting production, such as public stock and subsidies. This approach recognizes that government policies and interventions can have a direct impact on economic growth.
The criticism of the Solow growth model by North and Thomas (1973) is centered around their argument that innovation, economies of scale, and capital accumulation should be viewed as characteristics of growth rather than the causes of growth. They propose that institutions, which they define as the rules of the game in a society or the humanly devised constraints that shape human interaction, are the main explanation for growth leading to innovation and capital accumulation. Hassan and Gill-Gracia (2008) featured the institutional theory as fundamental to e-government research. It offers a thorough comprehension of the complex relationships between information technologies, organizational structures and processes, and institutional

arrangements. Institutional approaches are viewed as capable of taking into consideration recursive causalities between the different factors relating to e-government.

Acemoglu, Robinson, and Johnson (2005) highlight that economic institutions are the major source of cross-country differences in economic growth and prosperity. While cultural and geographical factors may also matter for economic performance, differences in economic institutions have a significant impact. Economic institutions not only determine the potential for aggregate economic growth but also influence various economic outcomes. Acemoglu, Robinson, and Johnson (2005) differ from previous research in that they viewed economic institutions as endogenous, meaning they are determined as collective choices of society. This is despite that individuals and groups may have different preferences for economic institutions due to the different distributions of resources associated with them.

The current study considers the possible endogeneity and reverse causality that could exist between e-government and economic development through the application of the Arellano–Bover/Blundell–Bond model for robustness check. The model is estimated using the Generalized Method of Moments.

Empirical Framework

There is a plethora of literature on the relationship between technology and economic development. However, the literature which quantifies the relationship between e-government and economic development is emerging. Majeed and Malik (2016) analyzed the impact of e-government on economic growth using a dataset of 147 countries, where the data from 2003 to 2012 is averaged to employ cross-sectional analysis. The study tested the relationship between the e-government indicators and economic growth using the Ordinary Least Squares method, then utilized two-stage least squares using instrumental variables of broadband subscriptions, share of urban population, and e-government lags. The study found that an increase in e-government score by 1% increases economic growth by a range of 1.9% to 2.7%.

Castro and Lopez(2021) examined the impact of e-government on economic development in 103 countries from 2003 to 2018, where economic development is proxied by national savings. The research indicates that nations with more advanced e-government systems are more likely to achieve sustainable development because the probability of positive adjusted net savings increases. In addition, developing and transitioning economies are more likely to experience growth in sustainable development compared to developed countries when their e-government systems become more advanced. This emphasizes the significance of investing in ICTs for governments in developing and transitioning economies.

The same result was found by Al-Refai (2020) who analyzed the relationship between economic growth and e-government in the six Gulf Cooperation (GCC) nations. The study found a positive relationship between the economic development index and economic growth in four of the GCC

countries. The sub-indexes of e-government were tested in a model comprising all of the GCC countries, and a positive significant relationship was found between economic growth and each of the telecommunication infrastructure and online service index.

However, Dhaoui (2020) investigated the impact of e-government on sustainable development in 15 MENA countries between 2003 and 2018. The study examined the impact of the e-government development index, e-participation index, and each of the three sub-indexes of the e-government development index on per capita GDP and several social development indicators in the MENA region. The study results did not support its hypotheses concerning a positive relationship between the e-government indexes and the economic and social development indicators. The study related the result to the lack of maturity of the e-government system in the MENA countries which does not avail them of the complete benefits of e-government.

Labhard and Lehtimäki(2022) examined the nexus between technology, governance, and economic growth in 103 countries grouped into EU, non-EU OECD, and other countries. Technology is represented by fixed broadband subscriptions and the percentage of individuals using the Internet. Governance is proxied by the corruption perception index and the world governance indicators. An interaction variable between those variables and technology is included. The study found a positive relationship between economic development, technology indicators, governance indicators, and the interaction between technology and governance in all country groups. Furthermore, Androniceanu and Georgescu (2021) found that e-government has a positive impact on economic growth in the European Union using principal component analysis where e-government is represented in a component comprising the e-participation index and one of the indicators of internet use. Ziolo et al. (2022) used a linear ordering method to analyze the relationship between the E-government development index and 10 indicators of environmental and socio-economic development in the European Union, where a positive relationship was confirmed. However, none of those publications examined the role of e-government on per capita GDP using all the e-government sub-indexes and the four indicators developed to measure the percentage of individuals who used the internet for e-government services in the European Union.

Thus, the current study contributes to the literature by analyzing the impact of e-government on per capita GDP in the European Union countries, where e-government is represented in two ways: (1) the e-government enablers, represented by the United Nations E-Government Development Index and its sub-indexes, namely, telecommunication infrastructure, human capital, online service, in addition to the e-participation index; and (2) Eurostat variables which gauge the individual's actual use of e-government services through three modes, particularly, obtaining information, downloading official forms, and submitting completed official forms online, in addition to the overall interaction with governments.

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Methodology

The paper employs panel data modeling to analyze the relationship between economic growth and e-government in the 27 European Union countries in addition to the United Kingdom. Economic development is measured using per-capita GDP. E-government is measured using different methods in model 1 and model 2. Model 1 relies on the E-Government Development Index (EGDI) published by the United Nations which is a weighted average of the three main pillars of e-governance: Online Service Index, (OSI), Telecommunication Infrastructure Index (TII), and Human Capital Index (HCI). The Online Service Index (OSI) is a comparative score based on assessments conducted by a consortium of United Nations experts and volunteers to assess the national electronic government portals of each country in the native language. The telecommunication infrastructure is a composite of five indicators, particularly, estimated internet users, number of main fixed telephone lines, number of mobile subscribers, number of wireless broadband subscriptions, and number of fixed broadband subscriptions per 100 inhabitants. The Human Capital Index (HCI) is composed of adult literacy rate, school, and tertiary gross enrolment ratio, and expected and current average years of schooling. Also, the E-participation Index (EPI) which is a supplementary index to the UN E-government survey is analyzed in the current study. It is based on a score that assesses, through survey questions, the use of online services to facilitate the provision of information by governments to citizens through electronic sharing of information, interaction with citizens through allowing them to contribute to and deliberate on public policies and services, and engagement of citizens in e-decision-making. Such indexes are available in 11 non-consecutive years from 2003 to 2022. (United Nations, 2022)

Thus, model 1 focuses on the assessment of the readiness and quality of e-government services in each of the European Union countries and the United Kingdom. Meanwhile, model 2 examines the actual use of e-government services through 4 variables which measure the percentage of individuals who use the internet to (1) interact with the government, (ii) download official forms, (iii) submit completed official forms, and (iii) obtain information about government services. This data is developed by Eurostat based on the annual survey on the use of ICT (Information and Communication Technologies) in households and by individuals. Such annual data is available from 2008 to 2021 (Eurostat, 2023). In addition to the e-government variables, each model employs a set of other variables that affect the level of per capita GDP, which include the inflation rate using the consumer price index, trade openness, labor force participation rate, gross school enrollment, gross capital formation as a percentage of GDP, and general government consumption as a percentage of GDP. Such annual data are obtained from the World Bank Development Indicators Database.

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The study adopts panel data analysis to estimate two main models with the following general form:

$$Y_{i,t} = \alpha + \beta Y_{i,t-1} + \gamma X_{i,t-1} + \eta_i + \varepsilon_{i,t} \qquad (1)$$

where Yi,t is the dependent variable which is per capita GDP, while X stands for a vector of explanatory Variables from them the measurements of e-government, which are the E-government index (EGDI), Online Service Index, (OSI), Telecommunication Infrastructure Index (TII), and Human Capital Index (HCI) in model 1, and the actual use of e-government services in model 2 through 4 variables, namely the percentage of individuals who use the internet to interact with the government(Interact), the percentage of individuals who use the internet to download official forms (download) (iii) the percentage of individuals who use the internet to submit completed official forms(submit), and the percentage of individuals who use the internet to obtain information about government services (obtain).

In addition to that, other variables are used as control variables, which are the inflation rate using the consumer price index, trade openness, labor force participation rate, gross school enrollment, gross capital formation as a percentage of GDP, and general government consumption as a percentage of GDP. Meanwhile, v_{it} and ε_i are the error terms.

The econometric estimation uses random effects and fixed effects models with cluster-robust standard errors in both model 1 and model 2. Robust standard errors and cluster-robust standard errors are estimated under both models to account for heteroscedasticity, whereas cluster-robust standard errors have the advantage of also accounting for autocorrelation (Cameron and Miller 2012; Hoechle, 2007). The results of both methods were similar; thus, only the estimation using cluster robust standard errors are reported in the study. This method is more appropriate than Feasible Generalized Least squares (FGLS) for the nature of the current study given that the number of countries is greater than the number of years, in addition that the FGLS could yield anti-conservative (optimistic) standard errors (Hoechle, 2007). For robustness check, the Arellano–Bover/Blundell–Bond model estimated using the Generalized Method of Moments (GMM) is utilized in model 2 to address the possible endogeneity and reverse causality that could exist between e-government and per-capita GDP. The Arellano–Bover/Blundell–Bond estimation employs differencing to transform all independent variables, with the assumption of no correlation between the fixed effects and the first differences of instrumental variables, which increases the model efficiency (Roodman, 2009). Accordingly, the first difference developed by Arellano and

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Bond's (1991) unobserved country-specific effect is removed as shown in the following equation (2):

$$Y_{i,t} - Y_{i,t-1} = \beta(Y_{i,t-1} - Y_{i,t-2}) + \gamma(X_{i,t-1} - X_{i,t-2}) + (\varepsilon_{i,t} - \varepsilon_{i,t}) \qquad (2)$$

There are two-moment restrictions introduced by Arellano and Bond (1991) to avoid the
correlation between the lagged dependent variable and the error term and avoid the existence of the endogeneity problem. These two restrictions; firstly, the disturbance terms are serially uncorrelated, secondly the regressors are assumed to be weakly exogenous which means that they are not correlated with the disturbance value of the present and the future but they might be correlated with the disturbance value of the past.

$E[Yi,t-n\ (\varepsilon i,t - \varepsilon i,t)] = 0$ for $n > 2; t = 3 \ldots \ldots T$
$E[Xi,t-n\ (\varepsilon i,t - \varepsilon i,t)] = 0$ for $n > 2; t = 3 \ldots \ldots T$

Results and Discussion

Data Description

Data Description of Model 1: E-Government Development Indicators

Table 1 shows a description of the data included in the model. The data covers the eleven years in which the EGDI has been published from 2003 to 2022, which are 2003,2004, 2005, then every other year starting 2008. The number of observations in the model is 279. Data on the e-government index(EGDI) and its subindexes is available for the 28 countries in the years in which the EGDI index is published; however, there are few missing data observations for the labor force participation rate.

It is important to note that the score of each country in the index is relative to the performance of the other countries included in the study. Therefore, an index of 1 does not mean that the country has exhausted all means of advancement in e-government. For example, the United Kingdom scored 1 in the e-participation index from 2003-2005, then its score was in the range of 0.43 to 0.98 in the later years.

Overall, a score of 1 on the e-participation index has been encountered a few times in the European Union countries in recent years, mainly in Denmark and Finland in 2018 and Estonia in 2020. Figure 1 plots the per capita GDP vs. the e-participation index in the European Union countries in 2022. The score in that year ranged from 0.45 in Belgium to 0.977 in Estonia. The two countries with the highest per capita GDP, namely Luxembourg and Ireland score in the mid-range along that score (0.75 and 0.68 respectively). The e-participation index, which is a supplementary index to the EGDI, is of particular importance given that it evaluates through survey questions, the use of e-government services by citizens. There is a high disparity in the European country's performance in that index compared to the EGDI overall index and sub-indexes.

As for the overall e-government index, the highest score was encountered in Denmark in 2020. In 2022, the top performers in the e-government index are Denmark, Finland, Sweden, and Estonia, while the lowest performer is Romania. The human capital index represents the smallest disparity among the EU countries as the country's score ranged from 0.731 to 0.993 in the study period, and from 0.81 to 0.933 in 2022. Meanwhile, the telecommunication infrastructure and online service index represent a higher range of disparity among the EU countries. It is notable that although Estonia ranks fourth among the EU countries in the overall EGDI in 2022, it ranked 10^{th} and 14^{th} in the telecommunication infrastructure and human capital index, but it is the top performer in the online service index at a score of 1.

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Table 1: Data Description of Model 1 The E-government Index and Its Sub-indexes

Variable Abbreviation	Variable Name	Mean	Std.Dev.	Min	Max	Unit of Measurement
PGDP	Per Capita GDP	29856.7	20682.83	4522.98	110095	Constant 2015 USD
EGDI	E-government Development Index	0.721	0.113	0.474	0.976	Score from 0 to 1
E-Part	E-Participation Index	0.528	0.287	0.017	1	Score from 0 to 1
TLCI	Telecommunication Infrastructure Index	0.597	0.182	0.149	0.998	Score from 0 to 1
HCI	Human Capital Index	0.911	0.058	0.731	0.993	Score from 0 to 1
OSI	Online Service Index	0.656	0.187	0.114	1	Score from 0 to 1
Inf	Inflation Rate	2.194	2.384	-1.540	15.400	Annual Percentage change of consumer price index
GCE	General Government Consumption	19.931	2.891	12.010	27.370	Percentage of GDP
GCF	Gross Capital Formation percentage of GDP	22.839	4.503	11.890	43.650	Percentage of GDP
TO	Trade Openness	118.113	63.696	46.150	365.22	Trade as a Percentage of GDP
LFPR	Labor Force Participation Rate	58.079	4.820	48.200	73.290	Percentage

Source: Data for PGDP, GCE, GCF, Inf, TO, and LFPR are from the World Bank Development Indicators Database (World Bank, 2023), while the e-government indexes (EGDI, E-part, TLCI, HCI, OSI) are from the United Nations Electronic Government Development Database (United Nations, 2023)
Note: The number of observations is 279

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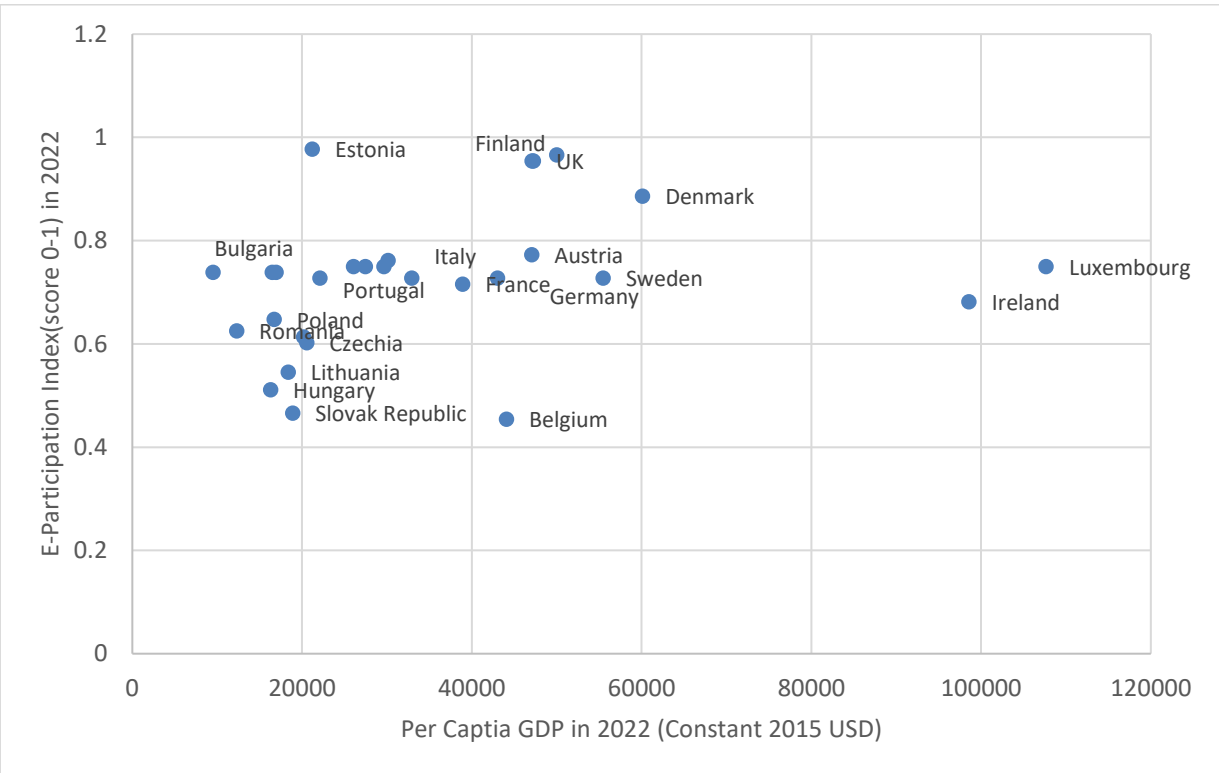
Figure 1: Per Capita-GDP vs. E-participation Index in the European Union Countries and the United Kingdom



Source: Developed by authors using data from the World Bank Development Indicators and United Nations EGDI- E-participation Index

Table 2 represents the correlation between the variables included in model 1. As expected, there is a strong positive correlation between the e-government index and most of its sub-indexes, except the human capital index. Therefore, each of the overall e-government indexes, telecommunication infrastructure index and human capital index, online service index, and e-participation index are modeled separately with the other independent variables that affect economic growth. In all cases, multicollinearity is tested through the variance inflation factor, and multi-collinearity was not detected in any of the models given that the variance inflation factor is below 10.

Table 2: Correlation Table of Model 1

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) PGDP	1.00										
(2) EGDI	0.62*	1.00									
(3) E-Part	0.38*	0.82*	1.00								
(4) TLCI	0.64*	0.91*	0.73*	1.00							
(5) HCI	0.26*	0.08	-0.17*	-0.12*	1.00						
(6) OSI	0.43*	0.92*	0.84*	0.72*	-0.04	1.00					
(7) Inf	-0.20*	0.00	-0.15*	-0.03	0.09	0.00	1.00				
(8) GCI	0.29*	0.43*	0.27*	0.36*	0.37*	0.32*	-0.12*	1.00			
(9) GCF	-0.18*	-0.17*	-0.23*	-0.23*	0.21*	-0.14*	0.39*	-0.14*	1.00		
(10)TO	0.24*	0.07	0.03	0.22*	-0.34*	0.01	0.06	-0.30*	0.05	1.00	
(11) LFPR	0.43*	0.45*	0.29*	0.45*	0.19*	0.32*	-0.15*	0.22*	0.03	0.04	1.00

Source: Authors' calculations
Note: Standard errors in parentheses * $p<0.05$

Data Description of Model 2: Use of Government Internet Services Indicators

The descriptive data of model 2 is provided in Table 3. The e-government indicators in this dataset are based on the Eurostat survey of government activities of individuals via websites(Eurostat, 2023).

Countries exhibited a high level of disparity during the study period from 2008 to 2021 in the percentage of the population using public services through the Internet. For example, the percentage of the population using the Internet to interact with the government(Interact) in 2021 ranged from 14.5% in Romania, and 92.25 in Denmark. In the same year, the percentage of individuals who used the Internet to submit completed official forms ranged from 9% in Romania to 79.5% in Sweden. Figure 2 shows that countries with a high level of the e-government index are not necessarily the countries with the highest level of actual use of the internet to submit completed forms, given that the e-government development index focuses more on the countries' capacity for e-government through telecommunication infrastructure, human capital index, and actual use of the internet to submit completed forms is a key indicator of the success of e-government service delivery.

Table 3: Data Description of Model 2

Variable Abbreviation	Variable Name	Mean	Std.Dev.	Min	Max
PGDP	Per Capita GDP, constant 2015 US	31052.360	20432.560	6294.390	110095
Submit	Percentage of the Population using the Internet to submit official forms	33.112	18.495	5.110	81.650
Obtain	Percentage of the Population using the Internet to obtain information	49.129	17.779	9.840	91.360
Download	Percentage of the Population using the Internet to download official forms	34.985	13.580	8.490	80.060
Interact	Percentage of the Population using the Internet to interact with government	54.774	18.138	12.260	92.250
Inf	Inflation Rate	1.655	1.949	-4.480	15.400
LFPR	Labor Force Participation Rate	58.659	4.758	48.140	73.360
School	Gross School Enrollment of primary, secondary, and tertiary education	110.080	16.298	87.970	163.930
GCE	General Government Final Consumption percent of GDP	20.134	2.995	12.010	27.930

GCF	Gross capital formation percent of GDP	21.868	4.490	11.890	54.950

Data source: Data for PGDP, GCE, GCF, Inf, TO, and LFPR are from the World Bank Development Indicators Database (World Bank, 2023), while the internet use variables are from Eurostat (2023)

Note: The number of observations is 281. "Gross" enrollment includes students of all ages. if there is late enrollment, early enrollment, or repetition, the total enrollment can exceed the population of the age group that officially corresponds to the level of education – leading to ratios greater than 100 percent.The correlation table exhibited in Table 4 illustrates a strong correlation between the different variables representing the use of government internet services(interact, obtain, download, and submit); hence, each of such variables is modeled separately with the other variables that affect per capita GDP(Inf, GCE, GCF, LFPR, School). Also, the Variance inflation factor which was performed after regression analysis did not indicate multicollinearity as discussed in the next section.

Table 4: Correlation Table of Model 2

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) PGDP	1.00									
(2) Interact	0.50*	1.00								
(3) Obtain	0.56*	0.88*	1.00							
(4) Download	0.44*	0.88*	0.82*	1.00						
(5) Submit	0.43*	0.97*	0.86*	0.82*	1.00					
(6) GCF	-0.17*	0.11*	0.03	0.09	0.11*	1.00				
(7) Inf	-0.31*	-0.20*	-0.19*	-0.19*	-0.19*	0.30*	1.00			
(8) GCE	0.23*	0.33*	0.30*	0.30*	0.37*	-0.12*	-0.14*	1.00		
(9) LFPR	0.40*	0.53*	0.44*	0.50*	0.54*	0.06	-0.08	0.10*	1.00	
(10) School	0.49*	0.41*	0.36*	0.54*	0.39*	-0.04	-0.30*	0.41*	0.23*	1.00

Source: Authors' calculations

*Note: Standard errors in parentheses, * p<0.05*

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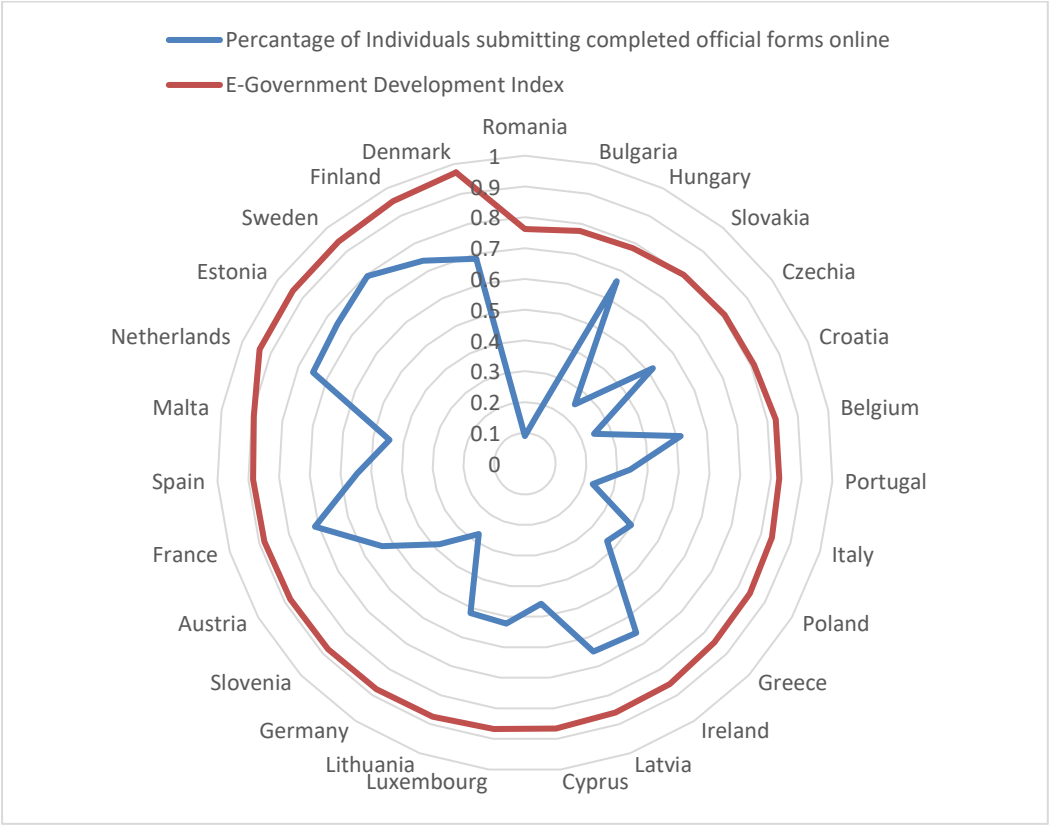

Figure 2: The percentage of individuals submitting completed official forms online in 2021 versus the e-government development index in 2020.

Source: Eurostat(2023) and United Nations (2023)

Econometric Estimation

Econometric Estimation of Model 1: The Relationship between Per Capita GDP and the E-government Index (EGDI) and each of its Subindexes

Tables 5 and 6 demonstrate the relationship between the logarithm of per capita GDP and the levels of the e-government index and its sub-indexes using random effects and fixed effects. The Beurch and Pagan Multiplier test for random effects indicated that the random effect should be used. There are minor differences between the results of the fixed and random effects, although the Hausman test indicated that the fixed effects model is more efficient. Cluster-

robust standard errors are employed to account for heteroscedasticity and possible autocorrelation (Hoechle, 2007)

Per capita GDP exhibits a positive significant relationship with the e-government index and its subindexes, where the p-value is 1% for the e-government development index, telecommunication infrastructure, and e-participation index, and 5% for the human development index and online service index. Ceteris paribus, with each advance in the e-government index score by 1 unit (the score ranges from 1 to 100), GDP per capita will increase by approximately 0.62% in the European Union countries. An improvement in the telecommunication infrastructure index score by 1 unit is associated with a 0.6% improvement in per capita GDP. This result is in line with Majeed and Malek (2016) who found that an increase in the e-government index by 1% increases per capita GDP is associated with 1.9% to 2.7% in per capita GDP in a sample of 147 countries.

An improvement in the human capital index by 1 unit increases per capita GDP by 0.34%. Both the telecommunication infrastructure index and the human capital index are measurements of the government's readiness for the application of e-government. On the other hand, the online service index gauges the quality of the e-government services provided. The online service index is a sub-index of the e-participation index, and their coefficients are remarkably close. Development in the online service index or the e-participation index score by 1 unit is associated with an approximately 0.15% increase in the country's per capita GDP level. The positive relationship between telecommunication infrastructure and economic growth has been confirmed by previous literature. For example, Sridhar (2007) emphasized the interrelation between economic development as a dependent variable and telecommunication infrastructure as an independent variable in the OECD developed countries, as well as developing countries. Also, Kotenok et al. (2020) confirmed such a relationship in a study that focused on Estonia and Ukraine. Roller et al. (2015) used a comprehensive set of variables to measure the relationship between economic growth and telecommunication infrastructure in twenty-one OECD countries and found a positive relationship as well.

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Table 5: Model 1: Fixed Effects Model of the Relationship between Per Capita GDP and E-Government Development Index (EGDI) and its Sub-Indexes

Dependent Variable: Log Per Capita GDP	**E-Government Index**	**Telecommunication Infrastructure and Human Capital**	**Online Index**	**E-Participation**
	(1)	(2)	(2)	(4)
EGDI	0.623***			
	(0.171)			
TLCI		0.609***		
		(0.123)		
HCI		0.366**		
		(0.158)		
OSI			0.151**	
			(0.0549)	
E-part				0.154***
				(0.0467)
Inf	-0.00632	-0.00164	-0.00850	-0.00478
	(0.00718)	(0.00562)	(0.00774)	(0.00767)
GCE	-0.0161*	-0.0238***	-0.0111	-0.0104
	(0.00811)	(0.00748)	(0.00873)	(0.00819)
GCF	0.00731*	0.00824**	0.00651	0.00684*
	(0.00368)	(0.00316)	(0.00392)	(0.00393)
TO	0.00207**	0.00139**	0.00281***	0.00240***
	(0.000790)	(0.000615)	(0.000891)	(0.000696)
LFPR	0.0170***	0.0144***	0.0185***	0.0189***
	(0.00492)	(0.00497)	(0.00535)	(0.00529)
Constant	8.572***	8.675***	8.670***	8.684***
	(0.332)	(0.325)	(0.379)	(0.436)
F-Test (p-value)	0.0000	0.0000	0.0000	0.0000
R-squared	0.551	0.633	0.4813	0.5134
Observations	279	279	279	279
Number of countries	28	28	28	28
Mean VIF	1.38	1.58	1.24	1.19

Source: Authors' calculations
Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Note: The mean Variance Inflation Factor (VIF) is based on the pooled ordinary least squares. However, the post-estimation correlation matrix did not indicate multicollinearity

Table 6: Model 1: Random Effects Model of the Relationship between Per Capita GDP and E-Government Development Index (EGDI) and its Sub-Indexes

Dependent Variable: Log Per Capita GDP	**E-Government Index**	**Telecommunication Infrastructure and Human Capital**	**Online Index**	**E-Participation**
	(1)	**(2)**	**(2)**	**(4)**
EGDI	**0.662*** **			
	(0.164)			
TLCI		**0.654*** **		
		(0.115)		
HCI		**0.546*** **		
		(0.164)		
OSI			**0.163*** **	
			(0.0447)	
E-part				**0.158*** **
				(0.0473)
Inf	**-0.00672**	**-0.00272**	**-0.00905**	**-0.00483**
	(0.00726)	**(0.00573)**	**(0.00784)**	**(0.00775)**
GCE	**-0.0139***	**-0.0219*** **	**-0.00898**	**-0.0107**
	(0.00815)	**(0.00754)**	**(0.00886)**	**(0.00826)**
GCF	**0.00744** **	**0.00819*** **	**0.00656***	**0.00688***
	(0.00372)	**(0.00311)**	**(0.00398)**	**(0.00397)**
TO	**0.00195*** **	**0.00138*** **	**0.00269*** **	**0.00245*** **
	(0.000565)	**(0.000409)**	**(0.000748)**	**(0.000702)**
LFPR	**0.0184*** **	**0.0162*** **	**0.0200*** **	**0.0196*** **
	(0.00479)	**(0.00478)**	**(0.00524)**	**(0.00531)**
Constant	**8.430*** **	**8.350*** **	**8.550*** **	**8.688*** **
	(0.229)	**(0.281)**	**(0.242)**	**(0.442)**
F-test(p-value)	**0.0000**	**0.0000**	**0.0000**	**0.0000**
R-squared	**0.5493**	**0.6301**	**0.4817**	**0.5132**
Observations	**279**	**279**	**279**	**279**
Number of countries	**28**	**28**	**28**	**28**
Mean VIF	**1.38**	**1.58**	**1.24**	**1.19**
Test for Random Effects	**0.0000**	**0.0000**	**0.0000**	**0.0000**
Hausman Specification Test	**0.0000**	**0.0000**	**0.0000**	**0.0000**

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Econometric Estimation of Model 2: The Relationship between Per Capita GDP and the Indicators of Actual E-Government Use by Individuals

Tables 7, 8, and 9 show the results of the relationship between per capita GDP and measurements of the populations' use of e-government services utilizing data from Eurostat (2023). Tables 7 and 8 show the results of the fixed and random effects models with cluster-robust standard errors to account for heteroscedasticity and possible autocorrelation. Table 9 shows the results of the Arellano–Bover/Blundell–Bond model. The Hausman test indicated that the fixed effects model is more efficient than the random effects. However, the estimates of the fixed and random effects models for the parameters of the main independent variables are remarkably close. The directions of the relationship between the main independent variables and per capita GDP did not change under the Arellano–Bover/Blundell–Bond model; however, the estimates of the Arrelano Bond model are more conservative. All the types of actual use of e-government services in the European Union demonstrate a positive significant relationship under the three models at a p-value of 1% (the only exception for 1% p-value is using the internet to download official forms under the fixed effects model which is 5%).

An increase in the number of people interacting with the government using the internet by 1% is associated with a 0.8% and 0.16% increase in per capita GDP under the Arellano–Bover/Blundell–Bond model and fixed effects model respectively. Meanwhile, an increase in the percentage of the population using the internet to obtain information from the government by 1% is associated with an increase in per capita GDP ranging from 0.06% under the Arellano–Bover/Blundell–Bond and 0.12% under the fixed effects model. Using the Internet to submit official forms is associated with a 0.044% increase in per capita GDP under the Arellano–Bover/Blundell–Bond model and 0.9% under the fixed effects model. Meanwhile, using the internet to download official forms is associated with a 0.06% increase in per capita GDP under the Arellano–Bover/Blundell–Bond and a 0.08% increase in per capita GDP under the fixed Effects model.

Overall, we conclude that per capita GDP is positively related to individuals' actual use of e-government services. The estimates indicate that an increase in the percentage of individuals using e-government services ranging from 10% is associated with a 0.4% to 1.6% increase in per capita GDP depending on the type of internet use and econometric estimation method, ceteris paribus. Therefore, the European Union countries should prioritize enhancing the use of e-government services, since citizen adoption is the litmus test for the implementation of e-government (Manoharan and Ingrams, 2018). Botrić, V., and Buožić (2020) examined the digital divide in e-government adoption across European Union countries as a main reason for the difference in e-government

adoption patterns among and within countries, and recommended training citizens on the use of e-government services especially the older female population in sparsely distributed areas.

Table 7: Model 2: Fixed effects model of the relationship between per capita GDP and actual use of government internet services to obtain information about government services, download and submit official forms, and interact with the government (Cluster-Robust Standard Errors)

Dependent Variable: Log Per Capita GDP	Obtain	Submit	Download	Interact
Log Obtain	0.123***			
	(0.0277)			
Log Submit		0.0944***		
		(0.0194)		
Log Download			0.0752**	
			(0.0300)	
Log Interact				0.166***
				(0.0253)
Log GCF	0.132***	0.124***	0.0963*	0.157***
	(0.0459)	(0.0442)	(0.0522)	(0.0405)
Log Inf	0.00389	0.00426	0.00104	0.00571*
	(0.00322)	(0.00330)	(0.00434)	(0.00279)
Log GCE	-0.319***	-0.354***	-0.390***	-0.281**
	(0.113)	(0.104)	(0.109)	(0.104)
Log LFPR	1.559***	1.395***	1.592***	1.433***
	(0.365)	(0.339)	(0.391)	(0.330)
Log School	0.202*	0.108	0.230**	0.163*
	(0.0984)	(0.0713)	(0.0920)	(0.0816)
Constant	2.982*	4.372***	3.249*	3.297**
	(1.635)	(1.436)	(1.628)	(1.530)
Observations	281	281	281	282
F-Test (p-value)	0.0000	0.0000	0.0000	0.0000
R-squared	0.601	0.643	0.556	0.654
Number of countries	27	27	27	27
Test for Random Effects	0.0000	0.0000	0.0000	0.0000
Hausman Specification Test	0.0000	0.0000	0.0000	0.0000

Source: Authors' Estimation
Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 8: Model 2: Random effects model of the relationship between per capita GDP and actual use of government internet services to obtain information about government services, download and submit official forms, and interact with the government (Cluster-Robust Standard Errors)

Dependent Variable: Log Per Capita GDP	**Obtain**	**Submit**	**Download**	**Interact**
Log Obtain	0.125***			
	(0.0183)			
Log Submit		0.0948***		
		(0.0107)		
Log Download			0.0800***	
			(0.0187)	
Log Interact				0.168***
				(0.0178)
Log GCF	0.133***	0.125***	0.0993***	0.159***
	(0.0325)	(0.0299)	(0.0342)	(0.0306)
Log Inf	0.00390	0.00421	0.00117	0.00572
	(0.00400)	(0.00373)	(0.00429)	(0.00373)
Log GCE	-0.305***	-0.343***	-0.368***	-0.268***
	(0.0631)	(0.0582)	(0.0662)	(0.0592)
Log LFPR	1.574***	1.410***	1.611***	1.447***
	(0.141)	(0.136)	(0.153)	(0.134)
Log School	0.212***	0.117**	0.244***	0.172***
	(0.0546)	(0.0538)	(0.0585)	(0.0515)
Constant	2.815***	4.221***	3.003***	3.138***
	(0.657)	(0.639)	(0.706)	(0.616)
F-Test (p-value)	0.0000	0.0000	0.0000	0.0000
Observations	281	281	281	282
R-squared	0.59	0.633	0.554	0.652
Number of countries	27	27	27	27
Hausman Specification Test	0.0000	0.0000	0.0000	0.0000
Test for Random Effects	0.0000	0.0000	0.0000	0.0000

Source: Authors' Estimation
Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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Table 9: Model 2: GMM model of the relationship between per capita GDP and actual use of government internet services to obtain information about government services, download and submit official forms, and interact with the government

Dependent: Log Per Capita GDP	(1) Obtain	(2) Submit	(3) Download	(4) Interact
Lagged Log PGDP	0.993***	0.993***	0.984***	0.987***
	(0.00750)	(0.00690)	(0.00978)	(0.00679)
Log Obtain	0.0621***			
	(0.0171)			
Log Submit		0.0439***		
		(0.00877)		
Log Download			0.0592***	
			(0.0127)	
Log Interact				0.0843***
				(0.0128)
Log Inf	0.00303	0.00455	0.00358	0.00515*
	(0.00242)	(0.00295)	(0.00305)	(0.00284)
Log GCE	-0.130***	-0.108***	-0.100***	-0.111***
	(0.0212)	(0.0238)	(0.0252)	(0.0243)
LOG GCF	0.0263	0.0359	0.0358	0.0351*
	(0.0232)	(0.0261)	(0.0241)	(0.0211)
Log LFPR	-0.0789	-0.179*	-0.0726	-0.190*
	(0.126)	(0.103)	(0.0985)	(0.101)
Constant	0.469	0.876**	0.457	0.809**
	(0.454)	(0.379)	(0.347)	(0.369)
Prob>Chi2	0.0000	0.0000	0.0000	0.0000
Observations	280	314	314	315
Number of countries	27	27	27	27
AR(2)	0.158	0.634	0.102	0.918
Hansen Test	0.999	0.999	0.999	0.995

Source: Authors' Estimation
Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Conclusions

The purpose of this paper was to examine the nature of the relationship between e-government and economic growth (measured by per-capita GDP) in the EU countries in addition to the United Kingdom using two sets of variables to measure e-government. A positive significant relationship was confirmed between economic growth and all of the variables used to measure e-government. An improvement in the telecommunication infrastructure index score by 1 unit is associated with a 0.6% improvement in per capita GDP. An improvement in the human capital index by 1 unit increases per capita GDP by 0.34%. Both the telecommunication infrastructure index and the human capital index are measurements of the government's readiness for the application of e-government. On the other hand, the online service index gauges the quality of the e-government services provided. The online service index is a sub-index of the e-participation index, and their coefficients are remarkably close. Development in the online service index or the e-participation index score by 1 unit is associated with an approximately 0.15% increase in the country's per capita GDP level, ceteris paribus. Furthermore, the estimates indicate that an increase in the percentage of individuals using e-government services by 1% is associated with a 0.04% to 0.16% increase in per capita GDP depending on the mode of internet use and econometric estimation method, ceteris paribus. Thus, the study highlights the contribution of e-government to economic growth in the European Union.

Based on these findings, the study recommends that governments prioritize investments in telecommunication infrastructure and human capital development to enhance their readiness for the application of e-government. By improving telecommunication infrastructure and investing in digital skills development, countries can create an enabling environment for e-government initiatives and maximize their impact on economic growth. The study also emphasizes the importance of regular monitoring of e-government implementation to assess its effectiveness and identify areas for improvement. Governments should establish mechanisms for continuous evaluation and feedback to ensure that e-government initiatives are meeting their intended goals and addressing the evolving needs of society.

The unavailability of long time series data on the e-government development index represented a limitation to the study. Due to its biennial nature, the index data was only available for 11 years. Additionally, the annual survey developed by Eurostat to measure the actual percentage of individuals using e-government services was only available from 2008 to 2021. However, such a survey proved to be useful for monitoring the actual implementation of e-government. It includes other types of data like the distinction between individuals using the internet based on several indicators, like age, gender,

geographic classification (rural or urban), disability, and status of employment. Such information is useful for a deeper understanding of whether e-government reinforces the inclusion or exclusion of specific groups of society like the disabled.

Thus, it is recommended that future research focuses on the following:

Inclusion of Digital Divide Factors: Future studies should consider including factors that reflect the digital divide, such as age, gender, geographic classification (rural or urban), disability, and employment status. By incorporating these variables, researchers can analyze how e-government initiatives impact different segments of society.

Standardized Surveys: It is recommended that standardized surveys be conducted in developing countries, similar to the annual survey developed by Eurostat. These surveys should follow consistent methodologies and data collection procedures to allow for cross-country comparisons and deeper analysis. This would enable policymakers to identify best practices and tailor e-government strategies to suit their specific contexts

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