sciendo
Review of Economic Perspectives – Národohospodářský obzor
Vol. 22, Issue 1, 2022, pp. 25–51, DOI: 10.2478/revecp-2022-0002

A theoretical framework to evaluate ICT disparities and digital divides: Challenges and implications for e-government development

Martin Lněnička[1], Renáta Máchová[2]

Abstract: Understanding and using ICT is critical for increasing effectiveness of the public sector, improving access to public services, enhancing transparency and engagement of various stakeholders in public decision-making processes. At the same time, utilization of new emerging technologies such as cloud computing, big data analytics, open data, social media, or Internet of Things has become more commonplace in recent years. This study aims to understand what determines ICT disparities and digital divides in the context of new technologies and digital world shifts. For this purpose, a theoretical framework of ICT-related indicators elucidating differences between the traditional and new approach is proposed. These ICT indicators were identified through the decomposition of related ICT and e-government indices together with explanatory factors derived from the literature. The European Union Member States were chosen as a sample for the exploratory analysis because of the availability of relevant indicators. More specifically, correlation, factor, regression, and cluster analyses were employed as empirical strategies to carry out this study. The Human Development Index together with research and development expenditure are the most important explanatory factors for the new approach, while the traditional set of indicators is still mostly correlated with the gross domestic product per capita. Finally, five clusters of Member States were identified and their implications for improving the use of ICT in the public sector are described.

Key words: cluster analysis, digital divide, e-government, European Union, exploratory factor analysis, ICT disparities

JEL Classification: C43, H11, L86, O38

Received: 11 May 2021 / Accepted: 12 January 2022 / Sent for Publication: 10 March 2022

[1] Science and Research Centre, Faculty of Economics and Administration, University of Pardubice, Studentska 84, 532 10 Pardubice, Czech Republic, martin.lnenicka@upce.cz
[2] Institute of System Engineering and Informatics, Faculty of Economics and Administration, University of Pardubice, Studentská 84, 532 10 Pardubice, Czech Republic, renata.machova@upce.cz

Introduction

The importance and impact of Information and Communication Technologies (ICT) were recognized by many studies and global reports (European Commission, 2015; International Telecommunication Union, 2018; United Nations, 2020; World Economic Forum, 2016). The opportunities created by ICT can decrease the gaps between countries. Generally, ICT create a number of benefits for governments, including the standardization of ICT resources, processes and policy-making, utilization and optimization of data infrastructure, efficiency of data transfer, analytics, storage, and costs of information management, or improving transparency and the relationships among citizens, businesses and public officials (Cuervo and Menendez, 2006; Doong and Ho 2012; Dutta and Lanvin, 2020; Helbig et al., 2009b; Jaeger and Thompson, 2003; Máchová and Lněnička, 2015; Waseda University, 2020). However, society is evolving rapidly, and needs are changing accordingly. Web applications, big and open linked data coupled with growth in Artificial Intelligence (AI), machine learning, cloud computing, mobile devices, and social media affect the concept of data analytics as well as information and services delivery (Barrenechea and Jenkins, 2014; Lachana et al., 2018; Lněnička and Komárková, 2019; Oxford Insights, 2020; Wimmer et al., 2020). In addition, the convergence of developments in hardware, software, and data availability provides another way to consider the trends in ICT (United Nations, 2018). Governments that ignore these opportunities and the use of the emerging ICT may suffer a loss of trust in their actions from citizens and businesses (Mohammed and Ibrahim, 2013; United Nations, 2020).

E-government is a key approach for achieving many of these goals. Therefore, we use it as a lens for the evaluation of ICT disparities and digital divides. It utilizes ICT to improve government communication, service, and transactional processes with its stakeholders (Jaeger and Thompson, 2003; Stoltzfus, 2005). More precisely, as defined by the United Nations (2014), e-government is "*the use and application of information technologies in public administration to streamline and integrate workflows and processes, to effectively manage data and information, enhance public service delivery, as well as expand communication channels for engagement and empowerment of people.*" Other organizations have their definitions of e-government as well, which differ in their emphasis on different points (Waseda University, 2020). E-government readiness (e-readiness) assesses "*the extent to which governments or economies are equipped to deliver various governmental services online and exploit ICT for internal functioning of the government*" (Ayanso et al., 2011). Hence, there should be a more focused understanding, examining, and explaining of e-readiness and its implications for the processes of e-government development and modern ICT adoption (Bannister, 2007; Bogdanoska-Jovanovska, 2016).

On the level of national economies, the impact of these technologies is discussed in the context of e-government benchmarking (Máchová and Lněnička, 2015). Its goal is to distinguish good practices from bad practices and provide incentives for improvements using a combination of a wide range of measures and indicators (Janssen, 2010). E-government benchmark studies are well established and widely disseminated (Bogdanoska-Jovanovska, 2016; Helbig et al., 2009a). Several reports, indices, and ranks have been published over consecutive years starting in 2000 by large intergovernmental entities such as the United Nations (UN), the World Bank, the World Economic Forum

(WEF), or the International Telecommunication Union (ITU). These represent a traditional approach to benchmarking and compare the performance of e-government development (Helbig et al., 2009a; Máchová and Lněnička, 2015). After 2010, new types of ICT-enabled applications and advanced services became more common and affordable. It meant a shift from traditional government to smart and sustainable government (European Commission, 2015; United Nations, 2020; Waseda University, 2020) in which more accessible, efficient, and user-focused public services are delivered (Máchová et al., 2018).

Because of the importance of ICT in defining the global digital divide, identifying how the ICT gaps and disparities among countries are created and maintained enables to avoid them (Billon et al., 2009; Chang et al., 2015; Doong and Ho, 2012; Helbig et al., 2009b). Many comparative studies were conducted to explore ICT disparities and digital divides in e-government development. The studies usually focus at either the national or municipal level and cover a range of topic areas including policy, implementation, management, impacts, or different factors such as economic, social, political, demographic, cultural etc. (Billon et al., 2009; Chang et al., 2015; Cruz-Jesus et al., 2018; Helbig et al., 2009a; Stoltzfus, 2005; Vicente and Lopez, 2011; Yera et al., 2020; Zhao et al., 2014). However, they did not always consider the current trends in ICT, although the need to continuously update the traditional concept and forms of benchmarking to address contemporary issues and technologies is emphasized in Cruz-Jesus et al. (2017), Cruz-Jesus et al. (2018), Elena-Bucea et al. (2020), Máchová and Lněnička (2015), Máchová et al. (2018), Ojo et al. (2011), or Ventura and Satorra (2015). Therefore, a new theoretical framework is needed to update the mix of indicators used to monitor ICT disparities and digital divides.

This study's exploratory empirical analysis is of significance in the domain of e-government benchmarking as it extends the knowledge base that presently exists in this field. Its main contribution is the novel approach to benchmarking e-government development and identification of the determinants of ICT disparities and digital divides by introducing two approaches: the traditional and the new one. In comparison with the previous studies, a larger number of variables is included, and a variety of explanatory factors is used. The European Union (EU) Member States are chosen as a sample for the exploratory analysis because of the availability of relevant indicators. Furthermore, the methodological approach employed in this study allows clustering all the EU Member States. It also provides both an update on the e-government benchmarking research activity and a complementary study to previous works and knowledge of how the role of new trends in ICT is influencing e-government development. Therefore, this study has implications for practitioners and policy makers in the adoption of new solutions and technologies to reduce ICT disparities and digital divides. It should be also noted that emphasizing the new approach and addressing it as a stand-alone concept is key to giving countries an overview of how they are doing in this area. Linking the new approach with the traditional one is then important because these approaches are not contradictory, but developmentally related and currently cannot be directly separated, because the spread of modern ICT is still limited and there is not enough data to replace the traditional view with the new one.

The paper is organized into seven sections, including the foregoing introduction. Then, the contextual background of ICT disparities and digital divides, e-government bench-

marking, and emerging trends in ICT is derived from an expanse of relevant literature. The next section addresses the methodological definition of the research with a theoretical framework and empirical strategy. The following section contains the data analysis and validation. After the description of indicators and explanatory factors, the results of correlation, factor, and cluster analyses are presented. The following section discusses implications and limitations for practitioners and policy makers. The final section presents the major conclusions.

Research background

Benchmarking e-government development

Governments are constantly looking for new ways to improve the quality of their e-government services (Kassen, 2014). This quality is measured through e-readiness indicators dealing with the country's technological and telecommunication infrastructure and the ability of its citizens and businesses to adopt, use, and benefit from ICT. These indicators then form benchmarking frameworks and models used to assess the effectiveness of e-government development (Dutta and Lanvin, 2020; Siskos et al., 2014; Máchová and Lněnička, 2015). These assessments are used to implement relevant strategies and initiatives to guide e-government processes (Rorissa et al., 2011; Stoltzfus, 2005; Zahran et al., 2015). They are conducted by various organizations, but sometimes they are based on a limited number of (subjective) indicators, reducing scopes of cross-comparisons, or do not highlight the multidimensional nature of electronically provided services (Ayanso et al., 2011; Siskos et al., 2014; Vicente and Lopez, 2011). According to Bogdanoska-Jovanovska (2016), there are three main types of e-government assessments focus (e-readiness, ICT intensity, and digital divide) as well as several sub-types of ICT intensity (external intensity: supply and demand, and internal intensity).

From a global perspective, the traditional approach is represented by the UN E-government rankings – the E-government Development Index (EGDI) and the E-participation Index, first published in 2003; the WEF's Networked Readiness Index (NRI), first published in 2002; the ICT Development Index (IDI) by ITU, first published in 2009, and the Waseda International E-government ranking, first published in 2005. After 2010, new indices and ranks focusing on the assessment of new ICT trends in e-government were introduced. The Open Data Barometer (2013–2017), the Open Data Inventory by Open Data Watch (ODW) and the OURdata Index, both first published in 2015, aim to assess coverage and impacts of open data and promote open government efforts. Government AI Readiness Index by Oxford Insights, first introduced in 2017, is designed to capture the capacity of governments to deal with the innovative potential of AI. The World Digital Competitiveness Index by International Institute for Management Development (IMD), first published in 2017, measures the capacity and readiness of selected economies to adopt and explore digital technologies. The commitment of countries to cybersecurity at the global level is assessed by the Global Cybersecurity Index, first introduced by ITU in 2015. Efforts to improve the quality of life through sustainable development using modern ICT are covered by the Environmental Performance Index by Yale University or the Sustainable Development Goals index by the UN.

There are also various studies which aim to revisit and reframe existing benchmarking frameworks with the use of modern technologies and trends such as cloud computing,

big data analytics, Internet of Things (IoT), electronic identification, social media, one-stop portal strategy, etc. (Lněnička et al., 2015; Máchová and Lněnička, 2015; Máchová et al., 2018; Mohammed and Ibrahim, 2013; Wimmer et al., 2020; Yera et al., 2020). The indices constructed with specific settings and assumptions may require matching the indices with appropriate purposes (Ayanso et al., 2011). Bannister (2007) claims that benchmarks may have a huge impact on political decision-making. Along similar lines, Kassen (2014) reported that the e-government agenda focuses more on achieving better governance than considering heterogeneous environments in different countries. Thus, the indices and rankings should be supported by well understood and clarified frameworks and transparent computational procedures to maximize their acceptability (Rorissa et al., 2011).

ICT disparities and digital divides

There are various studies that examine the relationship between ICT disparities and several socioeconomic characteristics at the cross-country, regional, and the individual level, such as Al-Mutawkkil et al. (2009), Chang et al. (2015); Cruz-Jesus et al. (2012), Cruz-Jesus et al. (2017); Cruz-Jesus et al. (2018); Elena-Bucea et al. (2020); Helbig et al., 2009b; Vicente and Lopez (2011), Ventura and Satorra (2015) or Zhao et al. (2014). There are two types of the digital divide. The first one is located at an international level, that is, between different countries. The second one is located at an intra-national level, or within a country (Cruz-Jesus et al., 2012). Vicente and Lopez (2011) identified two types of contribution to the literature on the digital divide. The first one is focused on measuring and quantifying the extent, evolution, and pace of the digital divide, while the second tries to explain the determinants of ICT disparities. However, measuring the access and use of ICT is a complex task influenced by several constraints (Cuervo and Menendez, 2006; Cruz-Jesus et al., 2012). These are mostly related to considerations about existing models and factors affecting ICT disparities and digital divides which differ between countries, geographical areas, and organizations. Cuervo and Menendez (2006) argued that there is a lack of harmonized data available when multiple countries are analysed, i.e., the more indicators are used, the fewer the countries that can be included in the analysis.

Billon et al. (2009) presented a cross-country study on the determinants of ICT diffusion using multivariate analysis techniques to capture the relative and multidimensional character of digital divides. Doong and Ho (2012) developed a framework to reduce multivariate raw data into an ordinal number representing the country's ICT development level. Chang et al. (2015) conducted a study to test the effect of the country development index on three levels of the digital divide. Also, a number of related studies rely on Exploratory Factor Analysis (EFA), or other multivariate models, to select the weights applied to a number of indicators to produce a single composite index or a single measure of e-government development (Al-Mutawkkil et al., 2009; Billon et al., 2009; Cruz-Jesus et al., 2012; Cruz-Jesus et al., 2017; Dodel and Aguirre, 2018; Vicente and Lopez, 2011; Ventura and Satorra, 2015). This technique is especially suitable for the analysis of the digital divide, considering the pervasiveness of ICT (Cruz-Jesus et al., 2012), and its wide set of applications, which require considering multiple dimensions.

On the level of countries, the ICT disparities and digital divides are often explored in the context of e-government adoption and diffusion. One of the reasons is that the pri-

vate sector is reluctant to invest in overcoming them and the responsibility is shifted towards governments. The most researched topics include the factors that influence the diffusion of e-government, the diffusion of e-government systems and applications, the impacts of e-government diffusion on government agencies and employees, and the relationships between ICT infrastructures and the diffusion of e-government (Zhang et al., 2014). Lakka et al. (2015) explored and evaluated the nature of the relationship between open-source software and e-government maturity, as well as the factors impacting their development at a national level. Their findings suggest that technological infrastructure and innovation are important drivers for open-source software growth across countries at all stages of development. A major purpose of a study presented by Krishnan et al. (2013) was to identify the country-level factors influencing e-government maturity. Their results showed that ICT infrastructure, human capital and e-participation had a direct relationship with e-government maturity. Abdel-Fattah (2014) studied the factors influencing the adoption and diffusion of e-government services and highlighted the importance of communication channels and service costs. Similarly, Yera et al. (2020) analysed the factors influencing the use of e-government in Europe and the different adoption levels to improve the interaction of citizens with web services and information offered by public sector agencies and institutions.

In sum, the comprehensive literature review allows the identification of a wide range of factors that may affect the disparities in ICT and digital divides at the national level. The diversity of these factors involved in the process reveals their multidimensional character and complexity (Ayanso et al., 2011; Billon et al., 2009; Siskos et al., 2014; Vicente and Lopez, 2011).

Emerging trends in ICT

The use of innovative technologies in the public sector moves e-government to a new stage in which machine-driven decisions are the foundation for the provision of customized services to citizens and businesses (Lachana et al., 2018; United Nations, 2018; Waseda University, 2020; Wimmer et al., 2020). Emerging infrastructures based on cloud computing provide resources for innovation processes driven by big and open linked data analytics, IoT, AI, and machine learning that aim to improve the availability and quality of online services. Cybersecurity is a key factor in the transformation to resilient e-government and deriving greater value from new segments such as IoT, connected devices, smartphones, wearables, and any kind of web-based services (International Telecommunication Union, 2018; United Nations, 2018).

These trends are affecting the transparency of government actions and the openness of public data. Not only governments are processing and using them, but open datasets are provided through open data portals to promote participation and knowledge sharing between citizens, governments, and other stakeholders (Kassen, 2014; Krishnan et al., 2013; Lněnička and Komárková, 2019). In addition, since governments, as well as other stakeholders, publish more and more open (linked) data through various portals, these data can be considered "big". The main reason is that these data are structured and can be analysed easier than unstructured big data. Of course, these data analytics models based on open (linked) data can be also enriched by semi- and unstructured big data. Thus, these terms are considered as complementary and create a single ecosystem (category) in which they are explored together (Lněnička and Komárková, 2019). Efficient

management of data and information flows among all the stakeholders can help to bridge the gap between them (Krishnan et al., 2013; Máchová and Lněnička, 2015; Lněnička and Komárková, 2019; United Nations, 2016; United Nations, 2018; Zissis and Lekkas, 2011).

New communication channels provided by social media can also play an important role in enabling data usage and online collaboration (Linders, 2012). The interactions should result in the provision of services that are responsive to the needs of citizens and businesses. According to Barrenechea and Jenkins (2014), these new services of e-government should be mobile, cloud and connected, open and transparent, intelligent, targeted, and participatory. Finally, in recent years, emerging green technologies have made significant technological advances and decreased in cost, especially with the cloud computing becoming more prevalent. They may help governments go green by centralizing all the resources and improve the resource utilization (Mishra et al., 2014). They are also closely related to sustainable development goals that aim to improve the quality of every living being's life (United Nations, 2020).

Therefore, since new technologies are continuously emerging, they should be considered in the assessment of ICT disparities and digital divides (Máchová and Lněnička, 2015; Ventura and Satorra, 2015, Wimmer et al., 2020). To ensure that the framework will be relevant to these trends and their composition, it is critical to include all indicators that have an effect on the diffusion of ICT into society.

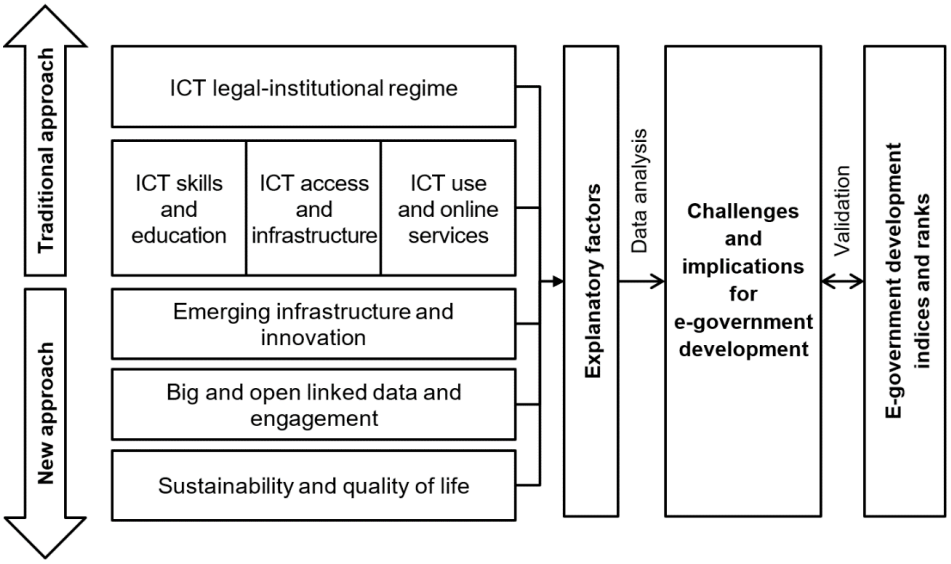
Theoretical framework and methodology

As a reference point for our research, data from international reports are chosen because it is the default level at which ICT disparities and digital divides are continuously evaluated. Furthermore, as demonstrated by Ayanso et al. (2011), individual indicators could be isolated from existing reports, or trends can be determined through empirical examination of these reports. Even very aggregate indicators can help to highlight the differences across countries and to identify their strengths and weaknesses (Archibugi and Coco, 2005). Thus, policy makers must be prepared to constantly refresh the basket of technologies that foster e-government development. It requires constant attention to new technology features (Cruz-Jesus et al., 2017; Cruz-Jesus et al., 2018; Máchová and Lněnička, 2015). If technology or infrastructure measures do not evolve over time, the indices can quickly lose relevance (Ayanso et al., 2011). Similarly, the analysis of a single technology separately does not provide much information about the level of e-government development within a country (Billon et al., 2009).

There is a research gap regarding the lack of indicators evaluating new trends in the context of ICT disparities and digital divides with a wide set of relevant and updated indicators. For this purpose, we developed a theoretical framework evaluating ICT disparities and digital divides that is depicted in Figure 1. The role of ICT in this study is seen to be constructed from two central elements, the traditional and new approaches. It should be also noted that both these approaches are complementary, not competing. The traditional approach to identifying the key sets of indicators is based on the ICT adoption process that progresses sequentially from the stage of having access to ICT, to developing use capability, and finally to achieving outcomes with the skills (Chang et al., 2015). This approach is followed by the benchmarking frameworks of the ITU's

Measuring the Information Society Report, the UN's E-government Survey, and the WEF's Global Information Technology Report (International Telecommunication Union; 2018; United Nations, 2020; World Economic Forum, 2016). The new approach then follows new ICT trends that should be considered in evaluating ICT disparities and digital divides. These were identified through the study of relevant literature and area-specific reports, such as AI readiness, open data, quality of life etc.

Figure 1. Theoretical framework of ICT disparities and digital divides



Source: own processing

The theoretical framework conceptualizes a country as a multidimensional system within which e-government development occurs. The model is based on the need to cover all ICT aspects relevant for the e-government development in a country. It is specified as shown in equation (1):

$$eGov_{i,t} = F\,(A_{tra}, A_{new}) \tag{1}$$

where $eGov_{i,t}$ is e-government development determined by two vectors of sets of indicators relevant to the traditional approach (A_{tra}) and the new approach (A_{new}) for each country (i) at time (t). These approaches can be also compared to each other or evaluated individually. Thus, they are expressed as follows in equations (2) and (3):

$$A_{tra,i,t} = F\,(X_{leg}, X_{ski}, X_{acc}, X_{use}) \tag{2}$$

$$A_{new,i,t} = F\,(Y_{eme}, Y_{ope}, Y_{sui}) \tag{3}$$

where X_{leg} is ICT legal-institutional regime, X_{ski} covers ICT skills and education, X_{acc} is ICT access and infrastructure, and X_{use} covers ICT use and online services. Then, Y_{eme} is focused on indicators of emerging infrastructure and innovation, Y_{ope} deals with big and

open linked data and engagement, and Y_{sui} covers indicators of sustainability and quality of life.

Furthermore, explanatory factors are tested to determine their influence on both traditional and new approaches. This then leads to the question of their implications for e-government development. This study analyses the publicly available data from e-government benchmarking reports and introduces a theoretical framework to evaluate ICT disparities and digital divides among the EU Member States. The choice of data in this research is further focused on the most current records of e-government benchmarking. Methods of multivariate analysis are used to accomplish this aim, i.e., correlation, factor, regression, and cluster analyses are applied.

Data analysis and validation

Data collection, description of indicators and explanatory factors

As reported in the previous sections, a new benchmarking framework should cover both traditional and new ICT-related indicators of e-government development. The authors used 30 variables that are compatible with recommendations from the EU, ITU, UN and WEF, and were mentioned in the literature review, e.g., by Cruz-Jesus et al. (2017) and Cruz-Jesus et al. (2018), as the most reliable option. These are represented by the variables and their description in Table 1. For the purpose of a cross-country comparison, this study relies on data from the most recent period. Following data collection, descriptive statistical methods were used to analyse these data in order to form a cross-comparative picture of ICT disparities and digital divides in the sample countries. Hence, Table 1 also shows some descriptive statistics about sets of these indicators. They reflect several important differences across the EU Member States, i.e., mean, standard deviation, minimum, and maximum.

The dataset of explanatory factors contains indicators that can be used to measure several factors mentioned in the previous sections. These factors are discussed and summarized in Hanafizadeh et al. (2013), where authors elaborated and classified 411 articles, conference papers, master's and doctoral dissertations, textbooks, and working papers on the digital divide and e-readiness. According to Nam (2014), the use of ICT for a specific purpose is predicted by five sets of determinants: psychological factors of technology adoption, civic mindedness, information channels, trust in government, and socio-demographic and personal characteristics. Lakka et al. (2015) emphasized the context of socio-economic, technological, and institutional factors. Billon et al. (2009) claimed that in countries with higher levels of ICT use, the digitalization pattern is explained by the Gross Domestic Product (GDP), service sector, education, and governmental effectiveness. Cruz-Jesus et al. (2018) focused on human-skills-related factors such as tertiary enrolment ratio. On the other hand, e-government has still not adequately embraced social resources, cultural factors, institutional structures, and governance networks (United Nations, 2014; Vicente and Lopez, 2011). Thus, the digital divide is a multidimensional concept, which requires a clear understanding of the related indicators, before implications for e-government development can be considered.

Table 1. Description of selected variables

Var.	*Description*	*Data source*	*Year*	*Range of values*	*Mean*	*Std. deviation*	*Min. / Max.*
ICT legal-institutional regime (traditional approach)							
Var1	Government effectiveness	World Bank	2019	-2.5–2.5	1.1	0.6	-0.3 / 1.9
Var2	Regulatory quality	World Bank	2019	-2.5–2.5	1.2	0.4	0.5 / 1.9
Var3	ICT regulatory environment	ITU	2019	0–100	91.8	3.8	85 / 99
Var4	International property rights index	PRA	2020	0–10	6.9	1.0	5.2 / 8.7
ICT skills and education (traditional approach)							
Var5	Adult literacy (%)	UNESCO	2018	0–100	98.8	1.1	94.5 / 99.9
Var6	Mean year of schooling	UNESCO	2018	no fixed range	12.0	1.1	9.3 / 14.2
Var7	ICT skills	WEF	2020	1–7	4.8	0.5	3.7 / 5.8
Var8	Total public expenditure on education (% of GDP)	UNESCO	2017	0–100	4.8	1.2	3.1 / 7.8
ICT access and infrastructure (traditional approach)							
Var9	Fixed-broadband subscriptions per 100 inhabitants	ITU	2019	0–100	34.2	6.6	20.6 / 45.7
Var10	Active mobile-broadband subscriptions per 100 inhabitants	ITU	2019	no fixed range	106.6	27.3	71.9 / 185.8
Var11	Percentage of households with Internet access	ITU	2019	0–100	86.6	5.7	75.1 / 96.2
Var12	International Internet bandwidth (kb/s) per Internet user	ITU	2016	no fixed range	438.7	1284.5	11.5 / 6890
Var13	Secure Internet servers per one million people	World Bank	2019	no fixed range	45.9	53.8	6.7 / 277.1
ICT use and online services (traditional approach)							
Var14	Percentage of individuals using the Internet	ITU	2019	0–100	84.6	7.2	67.9 / 98
Var15	Business use of digital tools	WEF	2020	1–7	5.4	0.5	4.4 / 6.2
Var16	Online service index	UN	2020	0–1	0.8	0.1	0.6 / 1.0
Emerging infrastructure and innovation (new approach)							
Var17	Adoption of emerging technologies	WEF	2020	1–7	4.4	0.7	3.2 / 5.7
Var18	Investment in emerging technologies	WEF	2020	1–7	4.2	0.8	2.9 / 5.7
Var19	Digital competitiveness index	IMD	2020	0–100	71.3	12.8	52 / 96
Var20	Government AI readiness index	Oxford Insights	2020	0–100	64.2	9.3	47.9 / 79.2

Var21	Global cybersecurity index	ITU	2018	0–1	0.8	0.1	0.5 / 0.9
Big and open linked data and engagement (new approach)							
Var22	Use of virtual social networks (% of population)	WEF	2019	0–100	61.0	10.1	45 / 91
Var23	E-participation index	UN	2020	0–1	0.8	0.1	0.6 / 1.0
Var24	Open data coverage	ODW	2020	0–100	62.4	10.4	44 / 82
Var25	Open data openness	ODW	2020	0–100	76.1	11.8	47 / 93
Sustainability and quality of life (new approach)							
Var26	Freedom to make life choices	Gallup	2020	0–1	0.8	0.1	0.6 / 1.0
Var27	Healthy life expectancy at birth (years)	WHO	2016	no fixed range	70.5	2.5	66.1 / 73.8
Var28	Environmental performance index	Yale University	2020	0–100	70.7	7.0	57 / 82.5
Var29	Quality of life index	Numbeo	2020	no fixed range	156.8	18.7	125.2 / 192.5
Var30	Sustainable development goals index	UN	2020	0–100	78.6	3.0	74.3 / 84.7

Source: own data processing

The first explanatory factor to consider is economic development measured by GDP at Purchasing Power Parity (PPP) per capita (Cruz-Jesus et al., 2018). The variable unemployment rate is included since economic development is clearly related to the situation of the labour markets (World Economic Forum, 2016). The unemployment and inflation rates are also emphasized in the context of e-government development in Lněnička (2015). Considering the above-mentioned impact of human capital on ICT adoption, three following variables are considered: the UN's Human Development Index, the percentage of population aged 15 and over, and the percentage of total population aged 65 and over (Krishnan et al., 2013; United Nations, 2016; United Nations, 2020). Since the EU has been paying special attention to bridging the rural-urban digital divide, population density has been analysed (European Commission, 2015). Finally, research and development expenditure as a percentage of GDP is considered as a source of technology generation (Archibugi and Coco, 2005). Table 2 shows selected explanatory factors. In order to study ICT disparities and digital divides in the context of e-government development, the following model can be defined as can be seen in equation (4):

$$\mathrm{ICT}_{i,t} = \mathrm{F}\,(\mathrm{eGov}_{i,t}, \mathrm{E}) \tag{4}$$

where F is a function of $eGov_{i,t}$ and a vector E of all the explanatory factors relevant to the evaluation of ICT disparities and digital divides ($ICT_{i,t}$) for each country (i) at time (t).

Table 2. Description of explanatory factors

Factor	*Description*	*Data source*	*Year*	*Range of values*	*Mean*	*Std. deviation*	*Min. / Max.*
GDP	GDP per capita, PPP (current $)	World Bank	2019	no fixed range	47464.4	19492.2	24789.6 / 121292.7
UER	Unemployment rate (annual %)	Eurostat	2019	0–100	6.1	3.3	2.0 / 17.3
INF	Inflation rate (annual %)	Eurostat	2019	no fixed range	1.7	0.9	0.3 / 3.9
HDI	Human development index	UN	2020	0–1	0.9	0.1	0.8 / 1.0
Pop15	The percentage of total population aged 15 and over	Eurostat	2019	0–100	84.4	1.5	79.5 / 86.8
Pop65	The percentage of total population aged 65 and over	Eurostat	2019	0–100	19.3	2.1	14.1 / 22.9
PopD	Population density (people per sq. km of land area)	World Bank	2018	no fixed range	181.8	282.2	18.0 / 1514.0
RaD	Research and development expenditure (% of GDP)	Eurostat	2019	0–100	1.7	0.9	0.5 / 3.4

Source: own data processing

Exploratory factor analysis

EFA is used to explore a dataset in order to determine relationships between observed variables and factors (Osborne and Costello, 2009). We used this analysis for the understanding of ICT disparities and digital divides among the EU Member States. EFA was performed using Statistica. First of all, it was necessary to assess the correlation between the variables. The correlation matrix showed that the relationships among most variables were at least moderately strong, with correlation coefficients (in absolute values) larger than 0.6 (Cohen et al., 2003). Then, the appropriateness of EFA was examined using the Bartlett's test of sphericity and the Kaiser-Meyer-Olkin's measure of sampling adequacy. The Bartlett's test of sphericity is used to test the hypothesis that the correlation matrix is an identity matrix. It is recommended for analyses where the sample size is relatively small (Bartlett, 1950). The Kaiser-Meyer-Olkin's measure takes values between 0 and 1. High values (between 0.5 and 1.0) indicate that EFA is appropriate and values below 0.5 imply that the correlations between pairs of variables cannot be explained by other variables and that EFA may not be appropriate (Kaiser, 1970).

In this case, Bartlett's test of sphericity confirmed that the overall set of correlation coefficients is significant at the level lower than 0.01, which suggests rejecting the null hypothesis. The overall Kaiser-Meyer-Olkin's measure was 0.61 (0.65 for traditional indicators and 0.71 for new indicators). All this indicates that the application of EFA is appropriate. Then, the Cronbach's alpha was applied to establish internal consistency and reliability. It measures how well a set of factors measures a single uni-dimensional factor. It should be 0.7 or higher. If it is exploratory research, 0.6 or higher is acceptable (Cohen et al., 2003). All seven sets of indicators had Cronbach's alpha exceeding 0.8, indicating good reliability in terms of internal consistency.

Therefore, a principal component analysis with Varimax rotation was carried out as an extraction method of EFA and the factors with an eigenvalue greater than one were extracted (Osborne and Costello, 2009). As shown in Table 3, six factors (latent dimensions) with an eigenvalue greater than one were extracted. These dimensions are similar to sets of indicators in Table 1, but not exactly the same. Variable 5 (adult literacy) is correlated to two different dimensions, on the boundary between traditional and new approach. Variable 12 (international Internet bandwidth (kb/s) per Internet user) is more related to ICT use and online services and variable 22 (use of virtual social networks) is more related to ICT access and infrastructure. Results for both traditional and new indicators in the context of EFA are also shown. They correspond to the original sets of indicators.

Table 3. Results of the EFA

All sets of indicators (EFA)			
Factor	*Eigenvalue*	*Percentage of variance*	*Cumulative percentage*
1	13.95	46.51	46.51
2	3.86	12.88	59.39
3	2.44	8.14	67.53
4	1.66	5.52	73.05
5	1.42	4.73	77.78
6	1.27	4.25	82.03
Sets of traditional indicators (EFA_{tra})			
1	7.38	46.09	46.09
2	2.19	13.65	59.74
3	1.63	10.18	69.92
4	1.13	7.05	76.97
Sets of new indicators (EFA_{new})			
1	7.23	51.61	51.61
2	2.11	15.09	66.70
3	1.25	8.91	75.61

Source: own data processing

After finishing all the required steps, a new e-government development score can be used to analyse the relationship between e-government development and explanatory factors to identify the determinants of ICT disparities and digital divides. The correlations between the new e-government development score (coming from Table 3) and explanatory factors are statistically significant at the level of 0.05. As can be seen in Table 4, the results are quite insignificant. The explanatory factor with the strongest influence on the traditional approach is the GDP per capita. The new approach is highly affected by the HDI and research and development expenditure. The high correlation between traditional sets of indicators and the GDP per capita was confirmed in Cruz-Jesus et al. (2017). It is affected by investments in telecommunication and network

infrastructures, while new indicators are mostly represented by services provided on these infrastructures. Human capital is an important factor in the context of ICT disparities and digital divides, especially in the case of new technologies. There is a negative linear relationship between the new e-government development score and unemployment and inflation rates. There is also no significant correlation between the new e-government development score and population-related factors.

Table 4. Correlations between the EFA scores and explanatory factors

	GDP	*UER*	*INF*	*HDI*	*Pop15*	*Pop65*	*PopD*	*RaD*
EFA	0.1801	-0.0106	-0.0916	0.6223	-0.4606	0.0905	-0.2400	0.7064
EFA_{tra}	0.8101	-0.1109	-0.1789	0.5900	-0.3615	-0.2784	0.2025	0.3228
EFA_{new}	0.5084	0.0641	-0.4069	0.7761	-0.3206	0.1053	0.0717	0.6285

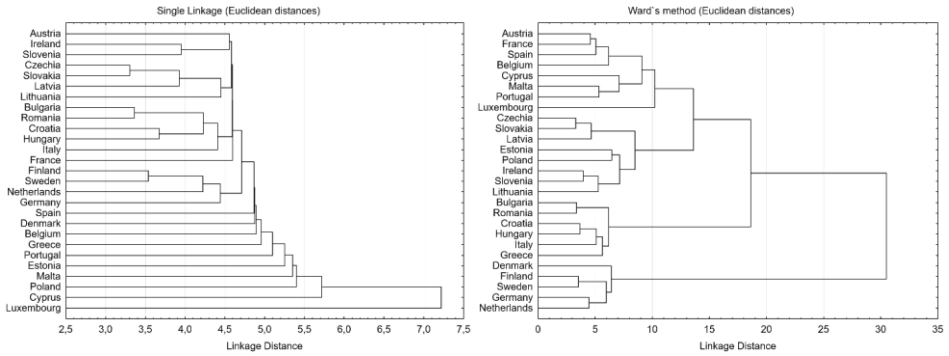
Source: own data processing

Cluster analysis

A cluster analysis was conducted for the original 30 variables to further evaluate selected indicators and identify clustering patterns which may affect ICT disparities and digital divides. The aim is to group the countries into clusters in such a way as to maximize the information provided on each of them. As the first step, a hierarchical single linkage algorithm and Ward's minimum variance method were used with Euclidian distance as a metric to obtain a preliminary solution for the next step. Then, a two-dimensional diagram known as a dendrogram was constructed to show the arrangement of hierarchical clustering. Based on these results, the k-means algorithm was used to determine the optimal number of clusters for the analysis. This methodology was applied in Máchová and Lněnička (2016).

The resulting dendrograms are shown in Figure 2. The non-hierarchical cluster analysis was done by means of algorithm k-means for four, five, and six clusters. From the given number, the highest quality clustering proved to be clustering for five clusters. This value was selected for further processing. The results are then shown in Table 5. The member of each cluster with the longest distance from the centre is in italic. Another output of the k-means algorithm is the graph of means for variables. By comparing clusters in this graph, the indicators that affect the clustering can be evaluated and digital divides can be identified. The corresponding graph is shown in Figure 3. The numbers of variables on the x-axis can be seen from the list of variables in Table 1. The results are discussed at the beginning of the following section.

Figure 2. Dendrograms for hierarchical cluster analysis



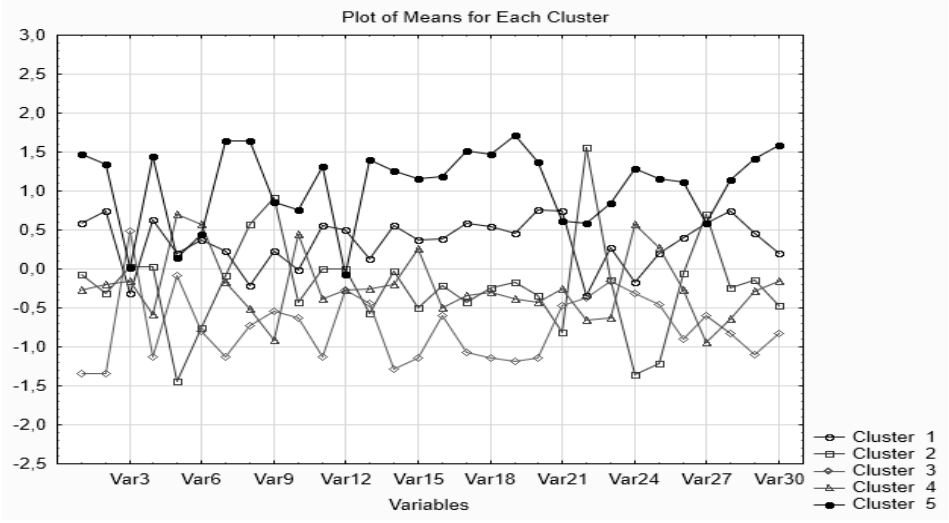
Source: own data processing

Table 5. The results of cluster analysis using the k-means algorithm

Cluster	*EU Member States*						
1	Austria	Estonia	France	Germany	Ireland	*Luxembourg*	Spain
2	Belgium	*Cyprus*	Malta	Portugal			
3	Bulgaria	Croatia	*Greece*	Hungary	Italy	Romania	
4	Czechia	Latvia	Lithuania	*Poland*	Slovakia	Slovenia	
5	*Denmark*	Finland	Netherlands	Sweden			

Source: own data processing

Figure 3. Graph of means for variables in each cluster



Source: own data processing

Validation against existing rankings

By computing the factor score of each Member State, a ranking can be developed to identify the best and worst performing countries. The main advantage of such a ranking is that it can be validated against existing e-government development indices. In this case, the EGDI and NRI from 2020 were selected because older rankings may not consider new technological developments, such as the IDI, which was last published in 2017, see Table 6. It should be noted that all these indices represent the traditional approach in e-government benchmarking (Máchová and Lněnička, 2015). When comparing these rankings, the first point to examine is the extent to which they are similar (Archibugi and Coco, 2005; Yera et al., 2020). According to Nardo et al. (2008), several correlation measures (measures of association) can be applied for this purpose. In this study, Spearman's and Kendall's rank correlation coefficients are used. Contrary to the Spearman's coefficient, the Kendall's coefficient is not affected by how far from each other ranks are but only by whether the ranks between observations are equal or not (Nardo et al., 2008).

Table 6. Ranking derived from EFA compared to existing indices

	Ranking derived from the EFA		*EGDI ranking 2020*		*NRI ranking 2020*	
Member State	*Score*	*Rank*	*Global*	*Among the EU*	*Global*	*Among the EU*
Austria	1.56	8	15	6	18	8
Belgium	1.59	7	41	20	20	10
Bulgaria	-3.79	26	44	22	46	26
Croatia	-2.07	22	51	25	43	24
Cyprus	-2.26	23	18	8	36	21
Czechia	-0.38	13	39	19	28	15
Denmark	4.36	2	1	1	2	2
Estonia	3.07	4	3	2	23	11
Finland	5.07	1	4	3	6	4
France	1.79	5	19	9	17	7
Germany	-0.70	17	25	14	9	5
Greece	-1.47	18	42	21	45	25
Hungary	-0.49	15	52	26	39	23
Ireland	-0.06	11	27	15	19	9
Italy	-1.89	20	37	18	32	18
Latvia	0.19	10	49	24	37	22
Lithuania	-0.43	14	20	10	29	16
Luxembourg	-2.41	24	33	16	11	6
Malta	-3.21	25	22	11	26	13
Netherlands	1.77	6	10	5	4	3

Poland	-1.80	19	24	13	33	19
Portugal	-2.00	21	35	17	31	17
Romania	-3.86	27	55	27	49	27
Slovakia	1.05	9	48	23	35	20
Slovenia	-0.67	16	23	12	27	14
Spain	-0.18	12	17	7	25	12
Sweden	3.87	3	6	4	1	1

Source: own data processing

As can be seen in Table 7, while the existing e-government development indices are correlated (over 0.7) between the rankings of each pair of indices, the new ranking derived from EFA is moderately correlated with these indices, finding the highest value with the NRI (0.66). These results were also confirmed by Kendall tau correlations in Table 8. All the correlations in both tables are statistically significant at the level of 0.05. Such results indicate that these traditional indices are not, or less, amenable to the idea of incorporating new trends in ICT into their benchmarking frameworks. One of the exceptions may be the Waseda International E-government ranking 2020, which evaluates most of the concepts related to ICT trends and e-government development including open government, cybersecurity, and the use of emerging ICT with three sub-indicators: the use of cloud computing, IoT, and big data (Waseda University, 2020). However, this ranking only covers 17 EU Member States, hence it cannot be accurately compared with others.

Table 7. Spearman rank order correlations

	EFA rank	*EGDI*	*NRI*
EFA rank	1.0000	0.5708	0.6587
EGDI	0.5708	1.0000	0.7662
NRI	0.6587	0.7662	1.0000

Source: own data processing

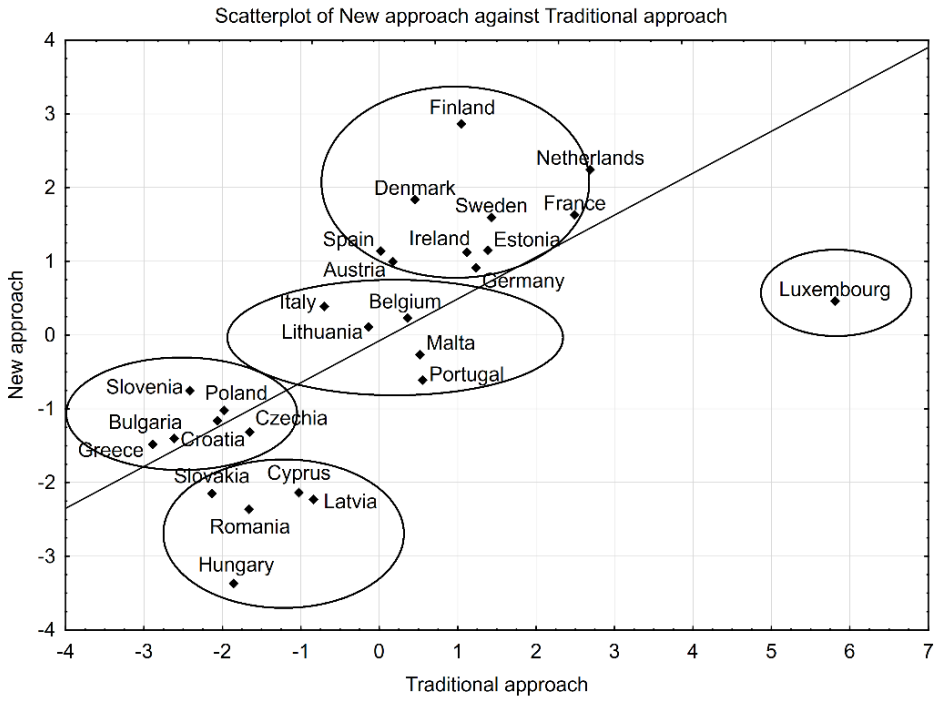
Table 8. Kendall tau correlations

	EFA rank	*EGDI*	*NRI*
EFA rank	1.0000	0.4245	0.5043
EGDI	0.4245	1.0000	0.5897
NRI	0.5043	0.5897	1.0000

Source: own data processing

Finally, factor scores for the traditional (sets of traditional indicators) and new (sets of new indicators) approach are compared with a scatterplot in Figure 4. Groups of Member States which tend towards one or the other approach can be seen there.

Figure 4. Scatterplot of the EU Member States groups



Source: own data processing

Results and discussion

The ICT disparities and digital divides in the level of e-government development among the EU Member States can be properly analysed with the use of previous results. With respect to the aim of this study, the findings should be focused on their challenges and implications for e-government development.

Taking a closer look at the clusters, the first cluster includes seven Member States and presents the second highest level of e-government development, except for big and open linked data and engagement. The second cluster consists of Member States countries with the highest achievements in big and open linked data and engagement. This area seems to have affected clustering the most. The lowest level of e-government development is represented by Member States in Cluster 3. The biggest weakness is their ICT legal-institutional regime. However, they perform quite well in big and open linked data and engagement efforts. This discrepancy may be due to the fact that some new technologies are, by their nature, capable of being applied despite obstacles represented by the traditional approach. The fourth cluster comprises six Member States from Central and Eastern Europe. They perform quite well in the context of traditional indicators and it can be assumed that these Member States have the necessary infrastructure telecommunication and network infrastructure to implement new trends in ICT and make related services widely available. There is also the potential based on values for sustainabil-

ity and quality of life. There are four Member States in Cluster 5. Their ICT legal-institutional regime and ICT access and infrastructure are set up to create the best conditions for e-government development. They perform best in all areas representing the new approach, especially in providing emerging infrastructure and innovation environment and achieving sustainable development goals.

Overall, the biggest ICT disparities are represented by big and open linked data and engagement, i.e., the reuse of open and linked data on related portals through engagement processes, and emerging infrastructure and innovation environment, i.e., improving the efficiency of ICT systems and services, like datacentres or telecommunication and network infrastructures. In the case of the traditional approach and its indicators, government effectiveness, respectively ICT legal-institutional regime, affects the digital divide between the EU Member States the most. The main consequence of this situation is that many countries do not provide advanced online services to their citizens and businesses and are still burdened by bureaucracy and paper pushing, especially in the EU Member States from Central and Eastern Europe. One observation is that the old Member States, in general, are putting more investments in new technologies compared to new Member States (those that joined after 2004). The only exception is Estonia. Therefore, these countries need to improve the implementation of new technologies. Better ICT access and infrastructure and more skilled and educated users of online services will result in improved opportunities for the use of new technologies and make them widely available. A new government enterprise architecture framework focusing on the big and open linked data issue with the use of cloud computing is also missing.

The results presented in this study agree with Cruz-Jesus et al. (2012), Cruz-Jesus et al. (2018) and Vicente and Lopez (2011). Thereby, it can be reaffirmed that within the EU, there is evidence that the most digitally developed countries are increasing their adoption and use of ICT in certain areas, even more so in the case of new technologies. However, the extent to which governments benefit from e-government depends on the stakeholders' willingness to adopt e-government. According to Abdel-Fattah (2014), both the willingness and intention of citizens are key measures of adoption. The development of e-government may itself represent technical innovation from which certain members of society are excluded (Nam, 2014), partly due to more complex types of interactions (Dodel and Aguirre, 2018). In other words, national governments often cannot achieve significant progress in building e-government projects without the participation of people due to weak promotion of the idea itself among stakeholders (Kassen, 2014; Máchová and Lněnička, 2015, Wimmer et al., 2020).

As reported by Zissis and Lekkas (2011), the capacity and tools to support effective citizen participation in the decision-making processes are still lacking in most e-government information systems. Not only social media and other traditional channels but especially the participation of stakeholders through relevant portals on national and local levels (smart cities) as well as promotion of web and mobile applications that reuse open data are crucial to engaging more of them in decision-making processes (Lněnička and Komárková, 2019; Nam, 2014). However, the adoption and implementation of these efforts to enhance e-government development can be hindered by economic, political, and technical factors (Abdel-Fattah, 2014).

To conclude, this discussion also suggests that policy makers should be prepared to face challenges that come with a successful implementation of these new technologies. In this case, the findings indicate that Finland, Denmark, and Sweden may be useful as the best practitioners to be considered in implementing them. Therefore, we highlight supporting the diffusion of new technologies since they will be dominant for any innovation in the future. The traditional approach should serve as a basis for these efforts on which the new approach should be built. Considering both these approaches, we can provide a broad view on all elements that may cause ICT disparities and digital divides. The results are important as a guide for future strategic decisions to improve the adoption and diffusion of e-government.

Implications and limitations

Implications for researchers and policy makers can be drawn from this study. One of the main implications comes from the close relationship between research and development expenditure and the overall e-government development. This claim is especially true in the case of investments in new ICT and services. This result is not considered to be surprising. However, it is necessary to emphasize this relationship to achieve sustainable development, with a special focus on the challenges in access to faster, scalable, and more efficient delivery of public services.

Therefore, policy makers should encourage digital diffusion of more advanced technologies corresponding to new trends in ICT. From this approach, new e-services, e-learning content, e-health, e-procurement, e-voting, e-management, e-democracy, etc. could help to promote advanced ICT diffusion (Barrenechea and Jenkins, 2014; Cruz-Jesus et al., 2017; Dutta and Lanvin, 2020; Máchová and Lněnička, 2015; Wimmer et al., 2020). But primarily, policy makers should concentrate on making emerging infrastructures available to all citizens. ICT skills are fundamental for engagement in today's information society and correlate positively with social well-being and economic productivity (International Telecommunication Union, 2018). Governments should also focus on boosting education levels across the whole population and invest in developing digital skills (United Nations, 2018). As recommended by the WEF, an emphasis should be placed on the quality of math and science education (World Economic Forum, 2016). The increasing power of ICT has provided governments with the flexibility and capability of providing services and information to citizens through new communication channels and IoT. Therefore, especially in the context of open government, open data portals on the national, regional as well as local levels (smart cities) should be launched to make public information easily accessible and to support the transparency efforts (Lněnička and Nikiforova, 2021).

Cloud computing technologies can offer cost savings to public sector institutions and help them go green. These results might be useful in finding and implementing the most suitable strategies and initiatives for each set of indicators analysed in this study. On the other hand, the adoption of emerging technologies by governments such as AI, blockchain, cloud computing, big data analytics, may inadvertently create new divides. Governments should create appropriate policies and regulations to stimulate the adoption of emerging technologies among stakeholders which would improve inclusion without

widening existing divides (Dutta and Lanvin, 2020; United Nations, 2018; United Nations, 2020).

This study has limitations which relate to two aspects of the analysis. The first aspect is related to the variables used in the development of the theoretical framework that are used in the related indices. Some of these indices are criticized due to their composition, the choice of the various technological dimensions, use of obsolete technologies or subjective indicators (Archibugi and Coco, 2005; Bannister, 2007; Rorissa et al., 2011). Besides that, collecting such a large volume of primary data is constrained by the number of resources available for conducting such research. As a result, most of the research on the cross-national level is based upon secondary data from related indices. The second aspect is the number of variables because it was found that some of these variables are only moderately correlated with their factors. However, while this study is exploratory and based on the differences between the approaches, it is crucial to cover all these variables. Their reduction can be investigated in future research.

Another limitation that should be considered is the small sample size together with the focus on the developed countries. However, as stated by Osborne and Costello (2009), in general, the stronger the data, the smaller the sample can be for an accurate analysis. This condition is fulfilled by the relatively homogeneous nature of the EU Member States. In addition, the availability of data for the new approach is still limited to developed countries. Furthermore, sometimes benchmarking approaches do not deal with the situation on territorial levels (in local governments) sufficiently. As stated by Zahran et al. (2015), most of the existing reports and studies have focused on national e-government even though local ones are closer to citizens. This analysis was conducted only on the national level, meaning that all indicators used are concerned with aggregated national realities, so regional or local digital divides are not covered. However, the EU provides several datasets for the NUTS 2 regions. Therefore, for future research, it would be of interest to extend the study of the digital divide to cover the local governments that have more information about their citizens' needs and what they want. This should help to better target policies and funding to reduce ICT disparities and digital divides and strengthen the use of e-government services.

Finally, the last limitation is related to the time dimension and how e-government is evolving through time. Since technological development and the e-government diffusion are dynamic and continuing processes (Zhang et al., 2014), our findings are valid for data available at the time. In addition, while dealing with the validation of the framework, it should be noted that older editions of indices and rankings may not consider new technological developments, and thus the validation may not provide results reliable enough for decision-making.

Conclusions

New trends in ICT have become a reliable force in transforming social, political, and economic life globally and an effective resource to reduce existing costs and stimulate transparency, accountability, and openness. As ICT are facilitating the flow of information and data between governments and other stakeholders, it is necessary to make progress towards improved access and use of modern ICT, especially broadband networks, cloud and mobile services, big and open linked data, new communication chan-

nels, and bridge the digital divide. Therefore, from a policy standpoint, efforts at bridging the digital divide must take this into account and provide several strategies, initiatives, and practices that are aimed at equal opportunities for ICT skills, access, and use.

The study's novel contributions include the connection of two approaches and clustering in the theory and practice of researching ICT disparities and digital divides in the context of e-government development. The theory introduced includes both ICT-related indicators and explanatory factors of e-government development and the tendency of the EU Member States to group together. The exploratory findings then show differences in the determinants of ICT disparities and digital divides and their implications on the national level, including characterization of clusters. The results of EFA were also validated against existing rankings. Overall, the Human Development Index together with research and development expenditure are the most important explanatory factors for the new approach, while the traditional set of indicators is still mostly correlated with the gross domestic product per capita.

Acknowledgements: For helpful comments and suggestions that improved the quality of this paper, we would like to thank the two anonymous referees.

Disclosure statement: No potential conflict of interest was reported by the authors.

References

ABDEL-FATTAH, M. A. K. (2014). Factors influencing adoption and diffusion of e-government services. In *14th European Conference on e-Government (ECEG 2014)* (pp. 1–9). Academic Conferences and Publishing International Ltd., Reading.

AL-MUTAWKKIL, A., HESMATI, A., & HWANG, J. (2009). Development of telecommunication and broadcasting infrastructure indices at the global level. *Telecommunications Policy*, 33(3-4), 176–199. https://doi.org/10.1016/j.telpol.2008.12.008

ARCHIBUGI, D., & COCO, A. (2005). Measuring technological capabilities at the country level: A survey and a menu for choice. *Research Policy*, 34(2), 175–194. https://doi.org/10.1016/j.respol.2004.12.002

AYANSO, A., CHATTERJEE, D., & CHO, D. I. (2011). E-Government readiness index: A methodology and analysis. *Government Information Quarterly*, 28(4), 522–532. https://doi.org/10.1016/j.giq.2011.02.004

BANNISTER, F. (2007). The curse of the benchmark: an assessment of the validity and value of e-government comparisons. *International Review of Administrative Sciences*, 73(2), 171–188. https://doi.org/10.1177/0020852307077959

BARRENECHEA, M. J., & JENKINS, T. (2014). *e-Government or Out of Government*. Waterloo, Ontario: Open Text Corporation.

BARTLETT, M. S. (1950). Tests of significance in factor analysis. *British Journal of Statistical Psychology*, 3(2), 77–85. https://doi.org/10.1111/j.2044-8317.1950.tb00285.x

BILLON, M., MARCO, R., & LERA-LOPEZ, F. (2009). Disparities in ICT adoption: A multidimensional approach to study the cross-country digital divide. *Telecommunications Policy*, 33(10-11), 596–610. https://doi.org/10.1016/j.telpol.2009.08.006

BOGDANOSKA-JOVANOVSKA, M. (2016). Demarcation of the field of e-government assessment. *Transylvanian Review of Administrative Sciences*, 12(48), 19–36.

CHANG, Y., KIM, H., WONG, S. F., & PARK, M. C. (2015). A comparison of the digital divide across three countries with different development indices. Journal of *Global Information Management (JGIM)*, 23(4), 55–76. https://doi.org/10.4018/JGIM.2015100103

COHEN, J., COHEN, P., WEST, S. G., & AIKEN, L. S. (2003). *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences*. New Jersey: Lawrence Erlbaum Associates.

CRUZ-JESUS, F., OLIVEIRA, T., & BACAO, F. (2012). Digital divide across the European Union. *Information & Management*, 49(6), 278–291. https://doi.org/10.1016/j.im.2012.09.003

CRUZ-JESUS, F., OLIVEIRA, T., BACAO, F., & IRANI, Z. (2017). Assessing the pattern between economic and digital development of countries. *Information Systems Frontiers*, 19(4), 835–854. https://doi.org/10.1007/s10796-016-9634-1

CRUZ-JESUS, F., OLIVEIRA, T., & BACAO, F. (2018). The global digital divide: Evidence and drivers. *Journal of Global Information Management (JGIM)*, 26(2), 1–26. https://doi.org/10.4018/JGIM.2018040101

CUERVO, M. R. V., & MENENDEZ, A. J. L. (2006). A multivariate framework for the analysis of the digital divide: Evidence for the European Union-15. *Information & Management*, 43(6), 756–766. https://doi.org/10.1016/j.im.2006.05.001

DODEL, M., & AGUIRRE, F. (2018). Digital inequalities' impact on progressive stages of e-government development. In *Proceedings of the 11th International Conference on Theory and Practice of Electronic Governance* (pp. 459–463). ACM, New York. https://doi.org/10.1145/3209415.3209475

DOONG, S. H., & HO, S. C. (2012). The impact of ICT development on the global digital divide. *Electronic Commerce Research and Applications*, 11(5), 518–533. https://doi.org/10.1016/j.elerap.2012.02.002

DUTTA, S, & LANVIN, B. (Eds.) (2020). *The Network Readiness Index 2020: Accelerating Digital Transformation in a post-COVID Global Economy*. Washington: Portulans Institute.

ELENA-BUCEA, A., CRUZ-JESUS, F., OLIVEIRA, T., & COELHO, P. S. (2020). Assessing the role of age, education, gender and income on the digital divide: Evidence for the European Union. *Information Systems Frontiers*, 1–15. https://doi.org/10.1007/s10796-020-10012-9

EUROPEAN COMMISSION. (2015). *Monitoring the Digital Economy & Society 2016 - 2021*. Luxembourg: Publications Office of the European Union.

HANAFIZADEH, M. R., HANAFIZADEH, P., & BOHLIN, E. (2013). Digital divide and e-readiness: Trends and gaps. *International Journal of E-Adoption (IJEA)*, 5(3), 30–75. https://doi.org/10.4018/ijea.2013070103

HELBIG, N., DAWES, S. S., MULKI, F. H., HRDINOVA, J. L., COOK, M. E., & EDWARDS, T. (2009a). *International Digital Government Research: A Reconnaissance Study (1994-2008)*. Albany, NY: Center for Technology in Government.

HELBIG, N., GIL-GARCIA, J. R., & FERRO, E. (2009b). Understanding the complexity of electronic government: Implications from the digital divide literature. *Government Information Quarterly*, 26(1), 89–97. https://doi.org/10.1016/j.giq.2008.05.004

INTERNATIONAL TELECOMMUNICATION UNION. (2018). *Measuring the Information Society Report 2018 – Volume 1*. Geneva: International Telecommunication Union.

JAEGER, P. T., & THOMPSON, K. M. (2003). E-government around the world: Lessons, challenges, and future directions. *Government Information Quarterly*, 20(4), 389–394. https://doi.org/10.1016/j.giq.2003.08.001

JANSSEN, M. (2010). Measuring and benchmarking the back-end of e-government: A participative self-assessment approach. In *Proceedings of the 9th IFIP WG 8.5 International Conference (EGOV 2010)* (pp. 156–167). Springer, Berlin Heidelberg. https://doi.org/10.1007/978-3-642-14799-9_14

KAISER, H. F. (1970). A second-generation little jiffy. *Psychometrika*, 35(4), 401–415. https://doi.org/10.1007/BF02291817

KASSEN, M. (2014). Globalization of e-government: open government as a global agenda; benefits, limitations and ways forward. *Information Development*, 30(1), 51–58. DOI: 10.1177/0266666912473620

KRISHNAN, S., TEO, T. S., & LIM, J. (2013). E-Participation and e-government maturity: A global perspective. In *Proceedings of the WG 8.6 International Working Conference on Transfer and Diffusion of IT (TDIT 2013)* (pp. 420–435). Springer, Berlin Heidelberg. https://doi.org/10.1007/978-3-642-38862-0_26

LACHANA, Z., ALEXOPOULOS, C., LOUKIS, E., & CHARALABIDIS, Y. (2018). Identifying the different generations of egovernment: An analysis framework. In *The 12th Mediterranean Conference on Information Systems (MCIS)* (pp. 1–13). Corfu, Greece.

LAKKA, S., STAMATI, T., MICHALAKELIS, C., & ANAGNOSTOPOULOS, D. (2015). Cross-national analysis of the relation of eGovernment maturity and OSS growth. *Technological Forecasting and Social Change*, 99, 132–147. https://doi.org/10.1016/j.techfore.2015.06.024

LINDERS, D. (2012). From e-government to we-government: Defining a typology for citizen coproduction in the age of social media. *Government Information Quarterly*, 29(4), 446–454. https://doi.org/10.1016/j.giq.2012.06.003

LNĚNIČKA, M. (2015). E-government development index and its comparison in the EU member states. *Scientific Papers of the University of Pardubice - Series D, Faculty of Economics and Administration*, 22(34), 75–87.

LNĚNIČKA, M., & KOMÁRKOVÁ, J. (2019). Big and open linked data analytics ecosystem: Theoretical background and essential elements. *Government Information Quarterly*, 36(1), 129–144. https://doi.org/10.1016/j.giq.2018.11.004

LNĚNIČKA, M., MÁCHOVÁ, R., & KOMÁRKOVÁ, J. (2015). Cloud e-government index as a new benchmarking framework for the public sector. In *Proceedings of the 19th International Conference Current Trends in Public Sector Research* (pp. 29–37). Masaryk University, Brno

LNĚNIČKA, M., & NIKIFOROVA, A. (2021). Transparency-by-design: What is the role of open data portals?. *Telematics and Informatics*, 61, 101605. https://doi.org/10.1016/j.tele.2021.101605

MÁCHOVÁ, R., & LNĚNIČKA, M. (2015). Reframing E-government development indices with respect to new trends in ICT. *Review of Economic Perspectives*, 15(4), 383–412. https://doi.org/10.1515/revecp-2015-0027

MÁCHOVÁ, R., & LNĚNIČKA, M. (2016). Modelling e-government development through the years using cluster analysis. *eJournal of eDemocracy and Open Government (JeDEM)*, 8(1), 62–83. https://doi.org/10.29379/jedem.v8i1.412

MÁCHOVÁ, R., KOMÁRKOVÁ, J., KOPÁČKOVÁ, H., & LNĚNIČKA, M. (2018). Benchmarking smart e-government development: Insights from a national perspective. *Scientific Papers of the University of Pardubice - Series D, Faculty of Economics and Administration*, 25(42), 152–164.

MISHRA, D., AKMAN, I., AND MISHRA, A. (2014). Theory of reasoned action application for green information technology acceptance. *Computers in Human Behavior*, 36, 29–40. https://doi.org/10.1016/j.chb.2014.03.030

MOHAMMED, F., & IBRAHIM, O. (2013). Refining e-government readiness index by cloud computing. *Jurnal Teknologi*, 65(1), 23–34. https://doi.org/10.11113/jt.v65.1759

NAM, T. (2014). Determining the type of e-government use. *Government Information Quarterly*, 31(2), 211–220. https://doi.org/10.1016/j.giq.2013.09.006

NARDO, M. et al. (2008). *Handbook on constructing composite indicators: Methodology and user guide*. Paris: OECD Publishing.

OJO, A., JANOWSKI, T., & ESTEVEZ, E. (2011). Building theoretical foundations for electronic governance benchmarking. In *Proceedings of the 10th IFIP WG 8.5 International Conference (EGOV 2011)* (pp. 13–25). Springer, Berlin Heidelberg. https://doi.org/10.1007/978-3-642-22878-0_2

OSBORNE, J. W., & COSTELLO, A. B. (2009). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Pan-Pacific Management Review*, 12(2), 131–146.

OXFORD INSIGHTS. (2020). *Government AI Readiness Index 2020*. Ottawa: IDRC.

RORISSA, A., DEMISSIE, D., & PARDO, T. (2011). Benchmarking e-government: A comparison of frameworks for computing e-government index and ranking. *Government Information Quarterly*, 28(3), 354–362. https://doi.org/10.1016/j.giq.2010.09.006

SISKOS, E., ASKOUNIS, D., & PSARRAS, J. (2014). Multicriteria decision support for global e-government evaluation. *Omega*, 46, 51–63. https://doi.org/10.1016/j.omega.2014.02.001

STOLTZFUS, K. (2005). Motivations for implementing e-government: An investigation of the global phenomenon. In *Proceedings of the 2005 national conference on Digital government research* (pp. 333–338). Digital Government Society of North America.

UNITED NATIONS. (2014). *United Nations e-Government Survey 2014: E-Government for the Future We Want.* New York: UN Publishing Section.

UNITED NATIONS. (2016). *United Nations e-Government Survey 2016: E-Government in Support of Sustainable Development*. New York: UN Publishing Section.

UNITED NATIONS. (2018). *United Nations e-Government Survey 2018: Gearing E-Government to support transformation towards sustainable and resilient societies*. New York: UN Publishing Section.

UNITED NATIONS. (2020). *United Nations e-Government Survey 2020: Digital Government in the Decade of Action for Sustainable Developmen*t. New York: UN Publishing Section.

VENTURA, E., & SATORRA, A. (2015). A multiple indicator model for panel data: An application to ICT area-level variation. *Telecommunications Policy*, 39(10), 830–847. https://doi.org/10.1016/j.telpol.2015.07.002

VICENTE, M. R., & LOPEZ, A. J. (2011). Assessing the regional digital divide across the European union-27. *Telecommunications Policy*, 35(3), 220–237. https://doi.org/10.1016/j.telpol.2010.12.013

WASEDA UNIVERSITY. (2020). *The 15th WASEDA International Digital Government Rankings Report*. Tokyo: The Institute of D-Government at Waseda University.

WIMMER, M. A., PEREIRA, G. V., RONZHYN, A., & SPITZER, V. (2020). Transforming government by leveraging disruptive technologies: Identification of research and training needs. *JeDEM-eJournal of eDemocracy and Open Government*, 12(1), 87–113. https://doi.org/10.29379/jedem.v12i1.594

WORLD ECONOMIC FORUM. (2016). *The Global Information Technology Report 2016: Innovating in the Digital Economy*. Geneva: SRO-Kundig.

YERA, A., ARBELAITZ, O., JAUREGUI, O., & MUGUERZA, J. (2020). Characterization of e-Government adoption in Europe. *PLoS ONE*, 15(4), e0231585. https://doi.org/10.1371/journal.pone.0231585

ZAHRAN, D. I., AL-NUAIM, H. A., RUTTER, M. J., & BENYON, D. (2015). A critical analysis of e-government evaluation models at national and local municipal levels. *The Electronic Journal of e-Government*, 13(1), 28–42.

ZHANG, H., XU, X., & XIAO, J. (2014). Diffusion of e-government: A literature review and directions for future directions. *Government Information Quarterly*, 31(4), 631-636. https://doi.org/10.1016/j.giq.2013.10.013

ZHAO, F., COLLIER, A., & DENG, H. (2014). A multidimensional and integrative approach to study global digital divide and e-government development. *Information Technology & People*, 27(1), 38–62. https://doi.org/10.1108/ITP-01-2013-0022

ZISSIS, D., & LEKKAS, D. (2011). Securing e-government and e-voting with an open cloud computing architecture. *Government Information Quarterly*, 28(2), 239–251. https://doi.org/10.1016/j.giq.2010.05.010