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E-Government Development in European Countries: Socio-Economic and Environmental Aspects

Magdalena Zioło [1], Piotr Niedzielski [2], Ewa Kuzionko-Ochrymiuk [3], Jacek Marcinkiewicz [4], Katarzyna Łobacz [2], Krzysztof Dyl [5] and Renata Szanter [5,*]

1 Institute of Economic and Finance, University of Szczecin, 71-101 Szczecin, Poland
2 Institute of Management, University of Szczecin, 71-007 Szczecin, Poland
3 Institute of Management, University of Bialystok, 15-062 Bialystok, Poland
4 Institute of Economics and Finance, University of Bialystok, 15-062 Bialystok, Poland
5 Institute of Security and Management, Department of Management, Pomeranian Academy in Slupsk, 76-200 Slupsk, Poland
* Correspondence: renata.szanter@apsl.edu.pl

Abstract: The purpose of the paper is to analyse the relationship between digitalisation of public services (e-government) and ESG factors (environmental, social and economic factors). As public administration is a major stakeholder influencing sustainable development and state governments are aiming to digitise their services, there is a need to better understand the effect of the digital revolution on ESG. This article aims to study the relationship between the E-Government Development Index (EGDI) and ESG factors in 26 European countries. The linear ordering method TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) was used for the study, followed by the Perkal index and the method of optimal predictors' selection—the Hellwig method. The study is based on the Eurostat data (in the period 2003–2020), and the analysis includes ten variables: Share of environmental taxes in GDP; Exposure to dust air pollution; Greenhouse gas emissions by source sector—carbon dioxide, methane, nitrous oxide, etc. (energy, industry, agriculture, forestry, waste management) (thousands of tonnes); Passenger transport volume in relation to GDP; At risk of poverty or social exclusion; Percentage of people satisfied with their financial situation among people aged 16+; Share of the ICT sector in GDP; Unemployment rate of people aged 20–64; Research and development expenditure in all sectors; GDP per capita. The in-depth analysis offers a matrix that represents the relationships between environmental taxes and the development of e-government. The main finding reveals statistically significant relationships between the EGDI and aggregate variables representing the environmental, social and economic spheres. It indicates a genuine, positive impact of digitalised administrative processes on sustainable development. It also seems to confirm that investments in digital infrastructure and government e-services bring multiple long-term benefits and contribute directly to all three domains relevant to the sustainability of modern development. The results of the analysis can be found useful by governments and governmental institutions as informing digitalisation strategies aimed at balancing the development of e-services and their support infrastructure. Nowadays, when planning strategic actions, one should take into account the social, economic and environmental impact of the digitalisation processes.

Keywords: e-government; sustainability; digitalisation; EGDI (E-Government Development Index); environmental factors; social factors; economic factors

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1. Introduction

Digital technologies are playing an increasingly important role in public administration. Although the origins of their use in governmental services entailed mainly the office settings, over the years, they have enriched the services that governments provide to the public, which is radically changing the nature of public administration [1]. The landscape

of e-services changes continually, reflecting strategies that governments are trying to implement to improve social, economic and political areas and to transform the decision-making process [2]. Digital technologies are changing governance mechanisms and are even seen by some researchers as drivers for the transformation of state functions [3]. There is also a growing demand of households and businesses for e-governmental services, who got used to technology-enabled lifestyles and expected similar public service solutions [4]. Therefore, it is important to keep in mind that digitisation of the public sector integrates digital technologies to add value, which requires rethinking and planning processes and information flows [5,6]. In [7], authors point out that the power of digitisation also lies in the combination and use of technological skills relevant to the digital world, such as sensing and acting (e.g., using GPS sensors), connecting (being able to link devices and transfer data), storing (using of cloud solutions) and processing (using of computing power) to solve problems and challenges faced by central and local government entities. They offer interesting examples of how these capacities can be combined in various systems providing new solutions and opportunities that can have an impact on eliminating, for example, adverse environmental impacts by providing online information on waste handling, displaying environmental effects, online tutorials, reading and recording energy consumption data in buildings, etc. In addition, the high rate of digital changes that are taking place in cities in regard to digitalisation, e.g., in terms of electrification or automation, is seen by researchers [8] as a threat to social and environmental sustainability but also as an opportunity to control an environmental impact. According to F. Creutzig and the other authors of the study [8], there is a need to provide directions to digitalisation by taking the top-down approach, e.g., urban management facilitated by digital platforms that support the integration of different means of communication and the exchange of information. The results of T. Meronen's [9] survey of Finnish public and private sector organisations indicate that a large proportion of them see a close connection between digitalisation and environmental sustainability. In this respect, sustainability could play a significant contributing role if long-term planning, intergenerational equity, risk reduction and resource conservation are considered in administrative planning [10]. Among the measures taken or planned, there are those related to the disposal of workstations and printers, energy saving or waste disposal. In the case of indirect measures with a positive impact on the environment, organisations are mostly implementing remote workstyle or carrying out processes using information and communication technologies. Digitisation can, therefore, have an impact on reducing energy demand or harmful emissions [11], but also the production, operation and disposal of digital devices or the operation of the entire IT infrastructure requires significant energy consumption, which raises the need to pay attention to the energy intensity of ICTs and to ensure that the benefits of their use, outweigh the costs incurred [12].

The rate of e-government development, analysed over the years using the EGDI (E-Government Development Index), is increasing worldwide. A clear trend has become the introduction of diverse e-government solutions, which is no longer a choice but has rather become a trend. In fact, there is now tremendous pressure from both citizens and the business sector for most government services and interactions to take place in an ICT-based environment. This pressure motivates governments to undertake costly ICT projects, often without sufficient understanding of the nature of the technology or the actual scope of the projects [13]. However, there are still clear regional differences due to different levels of development across countries. This also implies a differentiated potential impact on sustainable growth.

Thus, the aim of this article is to analyse the relationship between the digitisation of public services (e-government) and ESG factors (environmental, social and economic factors). As public administration is a major stakeholder influencing sustainable development, and as governments strive to digitise their services, there is a need to better understand the impact of the digital revolution on ESG.

The authors pose the following research questions: What is the direction and strength of the relationship between EGDI and ESG factors (environmental, social and economic)? Does investing in the development of digital infrastructure and public e-services have multiple real benefits in the long term and translate directly into all three areas relevant to sustainability in development? Are countries that have been digital pioneers in government currently experiencing positive changes in the economic, social and environmental areas?

The correlation analysis between the EGDI and the aggregated variables representing the environmental, social and economic spheres (using differentiated indicators) was conducted using the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) linear ordering method, followed by the Perkal index and the method for selecting optimal predictors, i.e., the Hellwig method. In addition, the study analysed correlations between variables describing the environmental, social and economic spheres and the EGDI variable using time lags. The correlogram made it possible to answer the question: after what time did changes in EGDI have the most noticeable effect in the environmental, social and economic spheres?

As the existing literature examining the correlation between e-government development and its impact on the economy, social development and the environment looks at these relationships separately and mostly focuses on economic and social aspects, the authors of the paper decided to conduct the analysis jointly in all three areas. The paper is the first to analyse the relationship between e-government development (with the use of the EGDI index for 26 European countries) and the environment, economy and social development, with an emphasis on the first of the relationships. The authors believe that there is a gap in research on the dynamics of digitisation in public administration and its impact on the environment and, therefore, opted for a time-lagged study. On this basis, they typified and interpreted the results.

The article consists of five sections. Section 1, Introduction, describes the social, economic and environmental background of the research undertaken. Section 2, Theoretical Framework and Research Problem, reviews the literature in the context of identifying a research gap in the relationship between e-government and exposure to environmental pollution, social exclusion and the percentage of people satisfied with their financial situation, as well as the contribution of the ICT sector to GDP, R&D expenditure in all sectors and the unemployment rate. The third chapter outlines the variables and describes the research methods. The main research results and discussion are presented in Section 4—Results and Discussion. Finally, the Section 5 presents the conclusions and the original contribution of the paper to the existing literature on the subject.

2. Theoretical Framework and Research Problem

2.1. Development of E-Government

The development of e-government can be tracked worldwide by analysing the United Nations E-Government Survey reports. Every two years since 2001, the United Nations Department of Economics and Social Policy has surveyed the level of development of e-government services in all 193 member countries. However, it is only since 2003 that the UN has presented the collected data in the form of a report.

Ten editions of the survey were published by May 2022: 2003 [14], 2004 [15], 2005 [16], 2008 [17], 2010 [18], 2012 [19], 2014 [20], 2016 [21], 2018 [22] and 2020 [23]. The next survey is announced for 2022.

The reports present the level of e-government development in each country. They also identify countries and areas where the potential of information and communication technologies (ICT) and e-government is exploited and which countries should be supported in their development.

The reports provide information that can be used by individual countries to identify the strengths and weaknesses of their own e-government and, consequently, to shape appropriate policies and strategies in this area. The report also serves as a resource for international bodies, including the United Nations General Assembly, the Economic and

Social Council and the High-Level Political Forum, to make decisions on issues related to e-government and its development at the international level. Moreover, the report can be referred to by government officials, policymakers and representatives of civil society and the private sector when making decisions on e-government in their own countries.

The document also provides the information necessary to further the 2030 Agenda for Sustainable Development [24]. The report is the only publication of its kind in the world.

The e-government development is measured according to the UN-developed EGDI (E-Government Development Index). This index is designed to assess the e-government development at the national level. It is a composite index based on a weighted average of three standardised indicators. Each of the three indicators, also composite measures, can be extracted and analysed independently.

One-third of the EGDI relies on the Telecommunications Infrastructure Index (TII) calculated from data provided by the International Telecommunication Union (ITU). Another one-third of the EGDI depends on the Human Capital Index (HCI), which is calculated from data provided by the United Nations Educational, Scientific and Cultural Organisation (UNESCO). The remaining one-third of the index depends on the Online Services Index (OSI). The OSI stems from information collected from an independent online services questionnaire (OSQ) by UNDESA [25] (United Nations Department of Economic and Social Affairs), which assesses the national online presence of all 193 UN member states. The above index also includes the E-Participation Index (EPI), an index complementary to the UN e-government survey that focuses on governments' use of online services in order to share electronic information, run e-consultation and make e-decisions.

The methodological basis for calculating the EGDI remained consistent across all survey periods, while its components (the three index-building indicators) were updated to reflect current trends in e-government, telecommunications and human capital.

It is worth noting that until 2008 the EGDI was treated as a measurement of e-government readiness (E-Government Readiness Index, EGRI). Only since 2010 has the name of the index been changed to the E-Government Development Index (EGDI) (with minor changes to the methodology).

The composite value of each component indicator discussed here is then normalised to fall between 0 and 1, and the overall EGDI value is obtained by taking the arithmetic mean of the three components. The report assumes that the value:

- falling between 0.001 and 0.25 represents Low EGDI,
- falling between 0.2501 and 0.50 represents Middle EGDI,
- falling between 0.5001 and 0.75 represents High EGDI),
- falling between 0.7501 and 1.00 represents Very High EGDI.

The EGDI values make it possible to create a ranking of countries according to their level of e-government development.

Given that the EGDI is relative in nature, caution should be exercised in interpreting changes in its value. This is especially true for countries with similar ranking positions. A higher position does not necessarily mean a significantly higher level of e-government development. Each country decides for itself the degree and range of its own initiatives in this area, drawing on its specific cultural context and development policies. These decisions may influence the ranking position, but this does not necessarily imply a significantly better or worse situation in a given country [26].

Proceeding to the analysis of information contained in the literature, it is evident that for the twenty years when the United Nations have been producing the reports, there has been marked progress in the development of e-government. In 2003, the average global level of the EGDI was 0.402 (i.e., it was at an average level), while in 2020, the indicator rose to 0.5988 (High-EGDI). In 2003, 10 countries enjoyed the highest level of EGDI, whereas, in 2020, the number rose to 55. At the same time, the number of countries with the lowest EGDI decreased from 55 in 2003 to just 8 in 2020.

When looking at the most recent 2020 report, it is worth noting that the group of countries with Low-EGDI consisted of 8 countries (as stated above), Middle EGDI was

reported by 60 countries, High EGDI by 70 countries, while Very High EGDI was seen in as many as 55 countries. Compared to 2018 (according to the 2018 UN E-Government Survey), 14 countries joined the group of countries with high and very high levels of e-government development. Consequently, in 2020 the cumulative percentage of countries with a high and very high level of e-government development reached as much as 65%. The top ten countries are Denmark, the Republic of Korea, Estonia, Finland, Australia, Sweden, the United Kingdom, New Zealand, the USA and the Netherlands.

In this paper, the authors focus on the EGDI in selected European countries.

Since the first edition of the UN e-government survey, Europe has always enjoyed the highest EGDI rate. In 2020, five European states belonged to the top 10 countries with the highest EGDI levels in the world. These were Denmark (ranked 1st), Estonia (ranked 3rd), Finland (ranked 4th), Sweden (ranked 6th) and the UK ranked 7th). All European countries boast a high or very high EGDI.

Europe has earned this success because, regardless of the environmental, social and economic issues at hand (i.e., the unfolding financial crisis, slowed economic growth, unemployment, as well as an ageing population), the European countries have actively sought innovative solutions to how to deliver public services to citizens. Most of the countries in the region, despite their difficult situation, decided not to reduce resources for e-government-related investments, while Austria, the Czech Republic, Estonia, Lithuania, Poland, Romania, Slovenia and Ukraine even increased them [23] (pp. 280–281). This resulted in the region improving its EGDI from 0.7730 in 2018 to 0.817 in 2020. The countries to improve their positions in the ranking the most were Lithuania (up by 20 ranking positions), the Czech Republic and Luxembourg (up by 15 positions), Slovenia (up by 14 positions) and Estonia (up by 13 positions). Table 1 shows the EGDI in Europe.

Table 1. EGDI in Europe in 2020.

Country	EGDI	World Ranking Position	Ranking Position in Europe
Albania	0.7399	59	35
Andorra	0.6881	80	41
Austria	0.8914	15	9
Belarus	0.8084	40	25
Belgium	0.8047	41	26
Bosnia and Herzegovina	0.6372	94	42
Bulgaria	0.798	44	28
Croatia	0.7745	51	31
Montenegro	0.7066	75	39
Czech Republic	0.8135	39	24
Dishes	0.9758	1	1
Estonia	0.9473	3	2
Finland	0.9452	4	3
France	0.8718	19	12
Greece	0.8021	42	27
Spain	0.8801	17	11
Netherlands	0.9228	10	6
Ireland	0.8433	27	18
Iceland	0.9101	12	7
Lichtenstein	0.8359	31	19
Lithuania	0.8665	20	13
Luxembourg	0.8272	33	20
Latvia	0.7798	49	30
Macedonia	0.7083	72	38
Malta	0.8547	22	14
Moldova	0.6881	79	40
Monaco	0.7177	64	36
Germany	0.8524	25	17
Norway	0.9064	13	8
Poland	0.8531	24	16
Portugal	0.8255	35	21
Russia	0.8244	36	22
Romania	0.7605	55	33
San Marino	0.6175	96	43
Serbia	0.7474	58	34

Table 1. *Cont.*

Country	EGDI	World Ranking Position	Ranking Position in Europe
Slovakia	0.7817	48	29
Slovenia	0.8546	23	15
Switzerland	0.8907	16	10
Sweden	0.9365	6	4
Ukraine	0.7119	69	37
Hungary	0.7745	52	32
United Kingdom	0.9358	7	5
Italy	0.8231	37	23

Source: Study based on [23] (pp. 280–281).

Summarising, it should be emphasised again that the level of EGDI has been increasing worldwide. Individual countries implement new e-government solutions every year, while regional variations of the index result from the level of development in individual countries.

2.2. Development of E-Government in the Context of Environmental, Social and Economic Factors

The first analysed group is environmental factors. The environmental policy framework set by the EU, as well as the environmental policies of individual countries, have an impact on the actors of economic life. The level of awareness and responsibility of companies in the sphere of doing business is changing. Companies are not just concerned with improving economic performance but are carefully evaluating their activities in terms of environmental impacts and social objectives. It is often the result of the environmental policies of the state and its obligation to introduce specific solutions, e.g., carbon dioxide reduction, waste disposal and recycling. What is more, consumers are increasingly often adopting a pro-environmental stance in their daily lives, which reflects their own convictions, growing environmental awareness as well as being a result of top-down imposed solutions, such as waste segregation and mandatory replacement of old furnaces. At the same time, being obliged by internal regulations and the requirements of the global environmental policy, central and local public administrations take actions that have an effect on the business community. What is also gaining considerable importance is the advancement of ICT and its increased use.

It is worth noting that the European Commission, in its European Green Deal Communication, points out that it is digital technology that is key to achieving the Green Deal sustainability goals in different sectors. Digital technology can have a significant effect on maximising the impact of actions addressing climate change and environmental protection. It also highlights the new opportunities offered by digitalisation, including remote monitoring of water and air pollution as well as monitoring and optimising the use of energy and natural resources. The document also points to the need for greater transparency regarding the environmental impact of electronic communications services and the need for stricter regulations.

As central and local governments are the principal stakeholders who have a bearing on environmental sustainability [27] (pp. 14–15), many authors are keen to better understand the impact of the digital revolution on the environment and to identify the link between e-government and sustainable development. A.M. Al-Khouri sees the need to integrate environmental sustainability into e-government strategy and objectives. He draws attention to saving time on transactions and interactions, reducing costs associated with transportation, saving paper or sharing and reusing technology. He also recognises the need to evaluate ICT infrastructure that may lead to inefficient energy consumption and to acknowledge the problem of electronic waste or high-energy infrastructure and applications, e.g., cloud computing centres, data centres, ultra-fast servers and cooling equipment [28].

Digitalisation can reduce energy demand or harmful emissions [11]. What is more, the production, operation and disposal of digital devices or the functioning of the entire IT infrastructure require large energy input [12]. It, therefore, seems important to prevent the energy intensity of ICTs so that the benefits of their use outweigh the costs incurred.

The successful implementation of e-government solutions is also determined by social factors, such as digital exclusion and public satisfaction.

Digital exclusion appears alongside the development of the information society. At a certain level of technological development, certain social groups (states) fail or lack the economic and social capacity to keep pace with civilisational progress. It affects those socially relevant places where certain groups remain underprivileged. What is characteristic of digital exclusion is its insurmountable capacity to aggravate dynamics corresponding to the development of information society technologies.

Digital exclusion and its causes are complex and, therefore, need to be considered from several aspects [29]:

1. Exclusion due to a lack of access to ICT (lack of appropriate devices, computers and no broadband internet);
2. Exclusion due to a lack of information society technology skills;
3. Exclusion due to a lack of confidence in ICT (a mental barrier) as well as a lack of knowledge about its usefulness;
4. Exclusion due to no access to properly developed technologies, which is particularly relevant for older people and people with disabilities;
5. Exclusion due to the failure of information society technologies to meet interoperability or technology neutrality requirements, particularly evident with regard to the so-called alternative software;
6. Exclusion due to language—a cultural barrier.

According to M. Rodino-Colocino [30], digital exclusion issues escalated in two waves:

1. Technological determinism, which sees technology as an automatic force that determines a new quality of life as well as a driver of social change (strong determinism);
2. Weak determinism, which sees technology as a factor facilitating the change and indirectly influencing the quality of life and the ongoing social change. This wave was accompanied by criticism of technological determinism.

The digital exclusion issues form a complex context. Digital exclusion cannot be alleviated only through the diffusion of ICT, as access to these tools proves useless if the potential user does not have the skills and knowledge to use the technology. The employment of ICT cannot be considered in terms of use/do not use, as it covers a whole range of uses, from simple applications to advanced ones [31].

Digital exclusion can, therefore, be defined by identifying the barriers that hinder and differentiate access to the above-mentioned resources. They are associated with Internet access and, above all, the quality of this access as well as with the skills to use the web, access information and communicate with other people. Moreover, these barriers reduce the chance that the produced content will reach a wide audience [32]. Digital exclusion also means any unequal access to the Internet, the degree of its use, knowledge of information-seeking strategies, as well as the quality of technical connections and social support to Internet use. It also encompasses inequalities in the ability to judge the quality of information and the diversity of applications [33].

E. Fong proposes a definition of digital exclusion in the context of computer and Internet use as differences between more and less developed countries, differences between adults and children (in terms of access to education), differences between people (education, income, occupation), and differences between geographical parts of countries (regions, rural and urban areas) [34]. In practice, the problem of digital exclusion is not about varied factors in the use of technology but about differences that lead to social or economic exclusion. Skills and methods of use are also important, as not every way of utilising computers and the Internet can produce positive consequences and improve individual life chances [35].

The OECD proposes a multifaceted and multidimensional definition of digital exclusion where it is seen as "the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard to both their opportunities

to access information and communication technologies (ICTs) and to their use of the Internet for a wide variety of activities" [36] (p. 5). In a similar vein, Manuel Castells concludes that "access to the web alone will not solve the problem, but it is a necessary condition for overcoming inequalities in societies whose essential functions and social groups are heavily dependent on the Internet." [37] (p. 276).

The last group to be analysed is economic factors that influence the development of e-government. They include elements that determine the use of ICT in specific industries and sectors and indicate areas with the highest productivity or employment. The development of information technology underpins the growth not only of the ICT sector but also of the economy and society as a whole. The competitiveness of industries is largely based on the availability and quality of ICT sector solutions. In times of global change, this is one of the key sectors for future growth.

The importance of the ICT sector in global economies is growing rapidly, as government investment and the creation of an innovation-friendly environment is a crucial element in stimulating the growth of the ICT sector and the economy. The flywheel of overall economic growth is, among other things, the increased efficiency of the main economic sectors through their computerisation. As well as contributing to economic development, the sector also has a positive impact on the social development of the EU Community. As a result of the production and provision of services based on increasingly advanced ICT technologies, there is an improvement in living standards and social welfare, as well as a boost in the sector's contribution to the EU's GDP, which consequently increases the total factor productivity that determines economic growth [38]. In recent years, the contribution of the three segments of the ICT sector (telecommunications, IT and media) has been in the range of 6–8% of the EU's GDP, playing a key role in job creation additionally. The sector is also focused on knowledge. The European ICT sector's share of R&D expenditure accounts for as much as 1/4 of total R&D expenditure by businesses in the European Union. Thus, the ICT sector ranked first among sectors in the European Union economy in terms of the amount of expenditure on R&D [39]. Most companies investing in R&D are located in the old 15 member states. Just under 98% of R&D expenditure is incurred in the EU-15, with companies from Scandinavia, Germany, France and the UK investing the most [40]. The ICT companies from the new member states present only a 2.6% share of total ICT sector expenditure in the EU. However, the European ICT sector's high R&D spending is below that of other world economies, such as the United States and Japan. Therefore the EU's priority remains to increase investment in research and to focus particularly on areas where it has an established, strong position as well as in emerging areas. This research is intended to increase Europe's international competitiveness in such important aspects as standards and R&D location decisions [41] (p. 9).

3. Methodology and Variables

Based on the analysis of the above variables, the authors attempted to investigate the relationship between the EGDI and environmental, social and economic factors in European countries. The level of the factors in each country was determined using the 2019 Eurostat data. The linear ordering method TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) was used for the study, followed by the Perkal index and the method of optimal predictors' selection—the Hellwig method. The study was guided by the principle of surveying as many European countries as possible, which significantly determined the number of variables adopted for the study.

The construction of synthetic measures of the phenomenon under study for individual variables proceeded according to the following procedure:

1. The variables used in the study were selected on merit (so that they indicated significant changes in the social, environmental and economic spheres) and in terms of statistics (so that they were sufficiently highly differentiated and had correspondingly low correlation coefficients with each other—in order not to duplicate the same information).

2. A list of potential explanatory variables was compiled, and their nature was determined, identifying stimulants and destimulants. If bigger values of the indicator are understood as favourable changes and indicate a higher level of development in a country, such an indicator will be called a stimulant. On the other hand, if higher values of the indicator imply a lower position of the country in terms of development, such an indicator will be called a destimulant. For the analysis, 10 explanatory variables were selected and divided into three groups (Table 2). In this way, 3 environment-related variables, 3 variables describing social factors, and 4 variables of an economic nature were identified.

Table 2. Variables used in the study.

	Environment
1.	Share of environmental taxes in GDP
2.	Exposure to dust air pollution
3.	Greenhouse gas emissions by source sector—carbon dioxide, methane, nitrous oxide, etc. (energy, industry, agriculture, forestry, waste management) (thousands of tonnes)
	Social
4.	Passenger transport volume in relation to GDP
5.	At risk of poverty or social exclusion
6.	Percentage of people satisfied with their financial situation among people aged 16+
	Economical
7.	Share of the ICT sector in GDP
8.	Unemployment rate of people aged 20–64
9.	Research and development expenditure in all sectors
10.	GDP per capita

Source: own elaboration based on [42].

3. All variables used in the study should be relative in nature, which facilitates a country's comparability in terms of the variable. The explanatory variables were normalised according to the formula of zero standardisation [43]:
for stimulants: $z_{ikt} = \frac{x_{ikt} - \min\limits_{i}\{x_{ikt}\}}{\max\limits_{i}\{x_{ikt}\} - \min\limits_{i}\{x_{ikt}\}}$
for destimulants: $z_{ikt} = \frac{\max\limits_{i}\{x_{ikt}\} - x_{ikt}}{\max\limits_{i}\{x_{ikt}\} - \min\limits_{i}\{x_{ikt}\}}$
where: i—country ($i = 1, 2, \ldots, n = 26$); k—indicator number of the phenomenon under investigation ($k = 1, 2, \ldots, m = 3\ lub\ 4$); t—year ($t = 2019$);
$\max\limits_{i}\{x_{ikt}\}$—the maximum k-value of this indicator of the phenomenon under study in the year under review,
$\min\limits_{i}\{x_{ikt}\}$—minimum k-value of this indicator for the phenomenon under study in the year under review

The study adopts a procedure with a common development pattern, the purpose of which is to be able to compare the data over the period under study. It should be borne in mind that there are other ways of normalising variables in the literature [43,44]: quotient transformation, standardisation or ranking of variable values. In this paper, normalisation with the use of the unitarisation formula is adopted, where after transformation, the variables have an equal range of variability (the interval of the transformed variable is equal to unity). The choice of standardisation method should consider the different properties of the transformed variables and the applicability of the formula depending on the type of scale on which the output variable is measured.

A principal issue, given the nature of the phenomenon under study and the analysis criterion adopted, is the assignment of weights to individual variables. For the purpose of the study, fixed weights were adopted, meaning that equal weight was given to each variable defining the sub-structure. This was considered when using the Perkal, Hellwig and TOPSIS methods. The adoption of other weights would have required deeper substantive analyses as well as relying on the expert method or on the available statistical data being a basis for the research conducted.

4. The next step was to build synthetic measures using the Perkal, Hellwig and TOPSIS methods

4.1. Perkal Index [45].

The Perkal method involves averaging the normalised values of individual indicators:

$$q_{it} = \frac{1}{n}\sum_{k=1}^{m} z_{ikt}$$

The values of the synthetic measure q_{it} elong to the interval <0.1>. Higher values of the synthetic measure indicate a higher position of the country in a given ranking.

Using the arithmetic mean ($\overline{q_t}$) and standard deviation (s_{qt}) for the value of the synthetic measure of the phenomenon under study, the countries were divided into four classes for t-th year 2019 according to the formula:

Class I (high level): $q_{it} \geq \overline{q_t} + s_{qt}$,
Class II (higher intermediate level): $\overline{q_t} + s_{qt} > q_{it} \geq \overline{q_t}$,
Class III (lower intermediate level): $\overline{q_t} > q_{it} \geq \overline{q_t} - s_{qt}$,
Class IV (low level): $q_{it} < \overline{q_t} - s_{qt}$.

4.2. Hellwig Index [46].

The countries' Euclidean distance from the development pattern $z^+ = (1, 1, \ldots, 1)$ was calculated according to the formula:

$$d_{0it} = \sqrt{\sum_{k=1}^{m}\left(z_{ikt} - z_k^+\right)^2}$$

Then, the reference distance d_{0t} was determined from the formula:

$$d_{0t} = \overline{d_t} + 2s_{dt}$$

where: $\overline{d_t}$—the average distance between objects and the development pattern in the t-th year 2019 determined according to the formula: $\overline{d_t} = \frac{1}{n}\sum_{i=1}^{n} d_{0it}$.

s_{dt}—the standard deviation in t-th year 2019, determined according to the formula:

$$s_{dt} = \sqrt{\frac{1}{n}\sum\left(d_{0it} - \overline{d_t}\right)^2}$$

The value of the synthetic measure of the phenomenon under study for the i-th country and t-th year was determined according to the formula:

$$q_{it} = 1 - \frac{d_{0it}}{d_{0t}}$$

These are the values of the synthetic measure (the measure may take negative values for an object for which the magnitudes of the variables differ significantly more strongly from those of the reference object than from other objects, and when the number of ordinal objects is large) [47,48]. q_{it} belong to the interval <0.1>. Higher values of the synthetic measure indicate a higher position of the country in a given ranking.

The linear ordering of countries by the value of their synthetic measure and the division of countries into four classes are described in list 4.1.

4.3. TOPSIS index [49].

The countries' Euclidean distance from a development pattern $z^+ = (1, 1, \ldots, 1)$ and anti-pattern $z^- = (0, 0, \ldots, 0)$ was calculated according to the formulae:

$$d_{it}^{+} = \sqrt{\sum_{k=1}^{m} \left(z_{ikt} - z_k^{+} \right)^2}$$

$$d_{it}^{-} = \sqrt{\sum_{k=1}^{m} \left(z_{ikt} - z_k^{-} \right)^2}$$

The values of the synthetic measure of the phenomenon under study were then calculated for the i-th country and t-th year:

$$q_{it} = \frac{d_{it}^{-}}{d_{it}^{-} + d_{it}^{+}}$$

- d_{it}^{-}—distance from the development anti-pattern for the i-th country in 2019
- d_{it}^{+}—distance from the development pattern for the i-th country in 2019
- q_{it}—value of the synthetic measure for *the* i-th country in 2019

4. Results and Discussion

The linear ordering of countries by the value of their synthetic measure and the division of countries into four classes are described in Section 3, list 4.1.

Table 3 shows the membership of the typological classes of the e-government development index (EGDI) and the aggregate variables describing the environmental, social and economic sphere in 2019 that were determined using the TOPSIS method.

Table 3. Results of analysis of relationship between e-government development index (EGDI) and environmental, social and economic variables determined with the TOPSIS method in 2019.

Country	EGDI	Environmental	Social	Economic
Belgium	3	3	2	2
Bulgaria	3	4	4	2
Bohemia	3	2	2	2
Denmark	1	3	1	1
Germany	3	1	2	2
Estonia	1	3	4	2
Greece	3	4	4	4
Spain	2	1	3	4
France	2	1	2	3
Croatia	4	4	3	3
Italy	3	4	4	4
Latvia	4	3	3	3
Lithuania	2	2	3	4
Luxembourg	3	3	2	1
Hungary	4	2	3	3
Netherlands	1	4	2	2
Austria	2	2	2	2
Poland	2	4	2	3
Portugal	3	2	4	3
Romania	4	2	4	3
Slovenia	2	3	2	3
Slovakia	4	2	2	3
Finland	1	2	1	2
Sweden	1	1	1	1
Iceland	2	2	2	2
Norway	2	1	1	1

Source: own elaboration, Legend: yellow—high, green—above average, orange—below average, red—low.

The group of countries best developed in terms of e-government level includes Denmark, Estonia, the Netherlands, Finland and Sweden, while the group of countries with the lowest e-government development rate consists of Croatia, Latvia, Romania and Slovakia. This may be due to public confidence, staff competence and the advancement of and access to technology in those countries, as well as demographic and environmental factors such as their geographical location or population density.

In addition, the study analysed the relationship between the variables describing the environmental, social and economic spheres and the EGDI variable with the use of time lags (different periods of time). The authors assumed that the values of the variables describing the economic, social and environmental spheres (from the year 2019) could be influenced not only by the current value of the e-government index but also by the value of the lagged EGDI (from earlier periods). This decision is due to the authors' assumption of the causal nature of the relations between the analysed spheres. The e-government development index is treated by the authors as one of the possible causes of changes in socio-economic development.

Significance testing for the correlation coefficient was performed by calculating the t statistic according to the formula [50]:

$$t = \frac{r}{\sqrt{1-r^2}}\sqrt{n-2}$$

and after transformations:

$$r^* = \frac{t_{\alpha,\, n-2}}{\sqrt{t^2_{\alpha,\, n-2} + n - 2}}$$

The coefficients whose absolute value exceeds *r** were considered statistically significant. The results and statistical significance of the analysed correlation coefficient values are shown in Table 4.

Table 4. Correlation coefficient value.

EGDI	Perkal (env. f.)	Perkal (social f.)	Perkal (ec. f.)	Hellwig (env. f.)	Hellwig (social f.)	Hellwig (ec. f.)	TOPSIS (env. f.)	TOPSIS (social f.)	TOPSIS (ec. f.)
2003	0.392 (**)	0.673 (***)	0.730 (***)	0.432 (**)	0.718 (***)	0.828 (***)	0.420 (**)	0.660 (***)	0.703 (***)
2005	0.458 (**)	0.708 (***)	0.756 (***)	0.502 (***)	0.738 (***)	0.835 (***)	0.465 (**)	0.693 (***)	0.750 (***)
2008	0.460 (**)	0.706 (***)	0.715 (***)	0.497 (***)	0.725 (***)	0.808 (***)	0.485 (**)	0.695 (***)	0.686 (***)
2010	0.457 (**)	0.658 (***)	0.633 (***)	0.490 (**)	0.680 (***)	0.732 (***)	0.473 (**)	0.653 (***)	0.597 (***)
2012	0.339 (*)	0.638 (***)	0.642 (***)	0.359 (*)	0.665 (***)	0.761 (***)	0.361 (*)	0.627 (***)	0.605 (***)
2014	0.410 (**)	0.484 (**)	0.429 (**)	0.431 (**)	0.520 (***)	0.569 (***)	0.422 (**)	0.466 (**)	0.379 (*)
2016	0.313 (-)	0.578 (***)	0.542 (***)	0.350 (*)	0.610 (***)	0.662 (***)	0.337 (*)	0.573 (***)	0.497 (***)
2018	0.333 (*)	0.562 (***)	0.562 (***)	0.369 (*)	0.615 (***)	0.677 (***)	0.355 (*)	0.543 (***)	0.512 (***)
2020	0.379 (*)	0.615 (***)	0.528 (***)	0.390 (**)	0.615 (***)	0.635 (***)	0.372 (*)	0.598 (***)	0.513 (***)

Source: own elaboration, Legend: *—level of significance (0.1); **—level of significance(0.05); ***—level of significance(0.01), -—no statistical significance.

The analysis of the correlation between the 2020 EGDI and the aggregate variables representing the environmental, social and economic spheres (using different indicators) shows statistically significant correlations. The environmental sphere is the least correlated with the 2020 EGDI variable (in the range of 0.372–0.390), while the EGDI variable correlates much more strongly with the social and economic spheres (in the range of 0.513–0.635). These correlation coefficients should be considered statistically significant at $\alpha = 0.01$. It can be concluded that the environmental sphere is somewhat less related to the development of e-government, as changes in this sphere occur much more slowly and the shape of this sphere depends on many factors, the effects of which are visible with a significant delay (e.g., terrain).

It should be noted that the use of the EGDI from earlier years increases the correlation coefficient in many cases. The maximum values of the correlation coefficients for the environmental sphere are seen for the EGDI of 2005, 2008 and 2010. This confirms the

authors' assumption of a slow, successive, albeit significantly lagged, impact of the analysed variable on the environmental sphere.

In their in-depth analysis of the variables describing the share of environmental taxes in GDP and of the EGDI, the authors attempted to create a matrix that represents the relationships of the above variables. In constructing the matrix, typification was performed using two criteria, taking values below the median (referred to as 'low' in the matrix) and above the median (referred to as 'high' in the matrix). The relationship between the above variables is shown in Tables 5 and 6.

Table 5. Relationship of the 2019 environmental taxes to the development of e-government in the analysed EU countries in 2020.

		EGDI	
		HIGH	**LOW**
SHARE OF ENVIRONMENTAL TAXES IN GDP	HIGH	Denmark, Estonia, Finland, Netherlands, Slovenia, Poland digital environmentalists	Belgium, Bulgaria, Croatia, Italy, Latvia, Greece, Portugal analogue environmentalists
	LOW	Sweden, Iceland, Norway, Austria, Lithuania, France, Spain digitisers	Czech Republic, Germany, Luxembourg, Romania, Slovakia, Hungary marauders

Source: own elaboration.

Table 6. Relationship of 2019 environmental taxes to the development of e-government in the analysed European Union countries in 2018.

		EGDI	
		HIGH	**LOW**
SHARE OF ENVIRONMENTAL TAXES IN GDP	HIGH	Denmark, Estonia, Italy, Finland, the Netherlands, digital environmentalists	Bulgaria, Croatia, Slovenia, Latvia, Greece, Portugal, Poland, Belgium analogue environmentalists
	LOW	Sweden, Iceland, Norway, Austria, Luxembourg, France, Spain, Germany digitisers	Czech Republic, Romania, Slovakia, Hungary, Lithuania marauders

Source: own elaboration.

When looking at the years 2018 and 2020, it can be seen that Germany and Luxembourg have moved from the 'digital environmentalists' box' to the 'marauders' box', while Lithuania has moved up from the 'marauders' box' to the ''digital environmentalists' box' and Italy has moved from the 'digital environmentalists' box' to the 'analogue environmentalists' box'. It is worth noting that although the negative changes in the EGDI in Germany, Luxembourg and Italy were minimal, e.g., Germany's EGDI decreased from 0.87 to 0.85 between 2018 and 2020, Luxembourg's EGDI fell from 0.83 to 0.82; it resulted in the shift of these countries into other typological groups. As regards the positive changes recorded in such countries as Poland, Lithuania and Slovenia, their EGDIs rose significantly, e.g., from 0.79 to 0.85 in the period of 2018–2020.

The majority of countries do not change their position in the groups and are, therefore, stable in the short to medium term, so it is difficult to forecast a radical change. The positions of these countries have not changed much.

As regards the social and economic spheres, the strongest correlation coefficients were seen, with the EGDI lagging by about 10–15 years. The analysis of the EGDI coefficient for the years 2003, 2005, 2008 and 2010 shows that many countries belonged to the lower classes of e-government development, which gradually became more homogenous in later years. The e-government development is less and less differentiated, as most countries have fallen into the high or very high EGDI class. The countries that were the first to implement

computerisation and digitisation in public administration offices are now experiencing positive changes in the economic and social sphere.

What explains the regularity of the correlation of the EGDI and the lag of about 10–15 years may be the concept of the impact of infrastructure on socio-economic development [51]. The development of technical infrastructure in the form of the provision of broadband Internet access services, together with the development of social infrastructure in terms of the ability to provide e-government services on this basis, is part of both the character of the infrastructure, such as a long time of implementation, as well as the diffusion [52] of new solutions related to the fact of providing e-government services. It is also important to bear in mind the specifics of telecommunications infrastructure and the diffusion of services that are provided thanks to its creation, i.e., the shorter payback period and accelerated diffusion according to the Schumpeterian long wave concept [53].

5. Conclusions

The analysis provides several conclusions of significant cognitive and practical importance, especially from the point of view of understanding growth factors and shaping economic policy directions. By highlighting the intensity of e-administration development processes, the authors pointed to their impact on the environmental, social and economic spheres that are relevant for sustainable growth.

Firstly, the observed correlation between the level of e-government development and environmental, social and economic areas seems to be of significance. This correlation implies that the digitisation of administrative processes can have a real impact on sustainable development, thus promoting positive change in all three of its spheres.

What seems extremely important for decision-making processes is the additional relationship revealed among the above areas investigated with regard to time lags. It confirms that investing in the development of digital infrastructure and government e-services brings real multiple long-term benefits and has a direct impact on all three areas relevant to modern sustainable development. This long-term relationship is particularly relevant to identifying environmental issues whose effects seem to appear clearly 10–15 years after the implementation of administrative measures. This is strongly evident in the case of the variable representing the contribution of environmental taxes to the GDP. This variable is regarded today as an indicator of our evolution towards the green economy.

The main limitation of this study is the lack of complete Eurostat data. The presented study was determined by the biannual nature of the publication of the United Nations E-Government Survey. The most recent survey was published in 2020. A significant constraint to the study was also the completeness of the variables presenting data from individual spheres. The authors faced the problem of choosing between the number of variables accepted for the study and the number of countries covered by the study. Thus, the number of countries was prioritised. The authors' intention was to maximise the number of European countries included in the study and to use at least three variables illustrating the sphere of environmental, social and economic factors in 2019.

The results of the above analysis may be useful for governments and state administration institutions in building digitalisation strategies for the years to come. The above indicates that it is important to maintain a good balance when creating e-services and building an appropriate infrastructure to support these services. Any considerable growth in one area not only does not affect the growth in terms of economic development but may also stunt it. A large number of offered e-services with insufficient infrastructure can make these services unavailable and thus discourage users in the future. Similarly, high saturation with infrastructure accompanied by low availability of e-services may negatively affect the willingness to use this infrastructure in the future.

The research results can be used by companies and administrations in their efforts to adequately prepare economies and countries to deal with such hardships as the COVID-19 pandemic. We could see how digitisation (e.g., in services, infrastructure, competencies) impacted the economy during the lockdown period. When forecasting strategic activities

nowadays, whether in companies or at the government level, it is necessary to take into account the importance, but also the influence of digital processes on the economy and their impact on the environment. Therefore, the results of this work constitute a valuable source of knowledge for the future authors of the above-mentioned strategy.

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