

DIGITAL EXCLUSION AND THE IMPLEMENTATION OF SELECTED SUSTAINABLE DEVELOPMENT GOALS IN EU COUNTRIES

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Article History:

- received 19 March 2024
- accepted 9 January 2026
- first published online 4 June 2026

Abstract. Dynamic development of digital technologies and the Internet in the 1990s. and the beginning of the 21st century significantly influenced the directions of social, economic and cultural development of societies in all countries of the world. A negative consequence of this process is the phenomenon of digital exclusion. The aim of this work is to measure this phenomenon in EU countries in 2023 and assess it in the context of the sustainable development goals. For this purpose, synthetic taxonomic measures were constructed using the TOPSIS method. The source of data was the Eurostat database, from which selected information from the ICT (Information and Communication Technologies) study and indicators describing the level of sustainable development. The research results show that EU countries were clearly differentiated in terms of the level of digital exclusion. This also had an impact on their implementation of selected sustainable development goals.

Keywords: digital exclusion, sustainable development goals, European Union countries, multivariate statistical methods.

JEL Classification: C38, O30.

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1. Introduction

The development of technology has always implied social, economic and cultural changes. This process undeniably improves the quality of life of individuals and entire societies, but it also has negative consequences. It is also always associated with the exclusion of certain individuals and social groups (Markowski, 2017), which is primarily a consequence of factors that include, among others:

- economic factors related to the possibility of purchasing and maintaining equipment and infrastructure,
- infrastructure factors, including technical aspects of access to new technologies,
- social factors related, on the one hand, to the level of development of society, education and culture, and, on the other hand, to the attitude of individual individuals to new techniques and technologies.

The rapid development of digital technologies in the second half of the 20th century, as well as the popularization of a new medium – the Internet – in the 1990s and the beginning of the 21st century constituted an evolutionary leap in the development of societies and economies in most countries of the world. However, this process has highlighted the problem

of digital exclusion of individuals and groups (Ragnedda et al., 2022), and the COVID-19 pandemic has highlighted it even more (United Nations, 2021). This phenomenon naturally affects socio-economic development (Popova et al., 2020), and therefore also affects the process of transforming economies in line with the principles of sustainable development (Worman, 2023).

The aim of this work is to analyze the phenomenon of digital divide in EU countries in 2023, as well as an attempt to determine its impact on the implementation of sustainable development goals (SDGs). Due to their thematic scope (United Nations, 2023), five of them were selected to analysis, which are logically related to the problem of digital exclusion: quality education (SDG 4), decent work and economic growth (SDG 8), industry, innovation and infrastructure (SDG 9), reduced inequalities (SDG 10), responsible consumption and production (SDG 12). The following research hypotheses were verified during the conducted research:

H1: *The phenomenon of digital exclusion affects the implementation of selected SDGs;*

H2: *The strength of the impact of the phenomenon of digital exclusion will be different for different SDGs;*

H3: *The quality of ICT infrastructure will strongly affect the implementation of selected SDGs.*

For the purposes of the analysis, synthetic measures were built which, on the one hand, described the skills of using the Internet and computer and the level of ICT infrastructure, and, on the other hand, the degree of implementation of selected SDGs in individual countries. The TOPSIS method was used for their construction.

Research related to the analysis of the impact of the digital exclusion on sustainable development is a novelty in the literature on the subject. The undeniable added value of this work is the deep statistical multidimensional analysis, covering 27 EU countries and enabling the detection of relationships between the analyzed phenomena.

The structure of this article includes an introduction that presents the main purpose of the work and explains the author's most important motivations for conducting the research. Section 2 reviews the literature, with particular emphasis on the problem of the lack of a coherent definition of the digital divide phenomenon, and provides a brief review of programs and initiatives aimed at limiting scope of analyzed phenomena. Section 3 discusses the statistical material constituting the basis for the analyzes performed and presents theoretical information regarding the TOPSIS method. Section 4 consists of a presentation and synthetic analysis of the obtained results, which were referred to in the form of a discussion in Section 5. The work ends with a summary.

2. Literature review

2.1. The problem of defining the phenomenon of digital exclusion (digital gap)

One of the basic problems related to the phenomenon of digital divide is the lack of a uniform and coherent definition. It is often related to the concept of social exclusion, which is understood as the lack of equal access to opportunities to provide services that enable

a dignified and happy life (Sanders, 2020) in relation to the “digital reality”. This may be due to the fact that some factors, such as income, place of residence, education, have a direct and inextricable impact on both of the above-mentioned phenomena (social and digital exclusion), although, as highlighted in the IPSOS MORI Scotland report (Martin et al., 2016), the exact relationship between them remains not fully explained.

Hence, the phenomenon of digital divide is often defined as a problem in access to infrastructure and devices enabling access to the Internet, resulting primarily from economic reasons (Gangadharan, 2021). According to this definition, as estimated by the UN (United Nations, 2022), 2.7 billion people were affected by it in 2022. More often, it is considered in a broader sense, through the prism of factors ranging from strictly behavioral factors: an individual’s motivation, mental motivation, aversion to technology, through the level of education, income, and ending with racial (Stanford University, 2000; Tomczyńska, 2017).

Due to the lack of a single, coherent definition of the digital divide phenomenon, this phenomenon is often understood differently by various entities and institutions, including international ones, such as:

- National Digital Inclusion Alliance (2022);
- International Telecommunication Union [ITU], 2022);
- United Nations Human Settlements Programme (2021);
- Eurostat (n.d.-f);
- Organisation for Economic Co-operation and Development [OECD], (2001).

Although all the definitions seem to be similar, they differ in several aspects. They clearly emphasize the so-called “hard” causes of digital exclusion (Bartol et al., 2021), i.e., lack of access to telecommunications technologies and/or the Internet, directly related to infrastructure limitations (lack of access services, lack of appropriate hardware and software, etc.). Economic reasons are also emphasized. In this aspect, according to the author, there appears the first weakness of some of the presented definitions. Although services related to the transmission of data are one of the symbols of technological development at the turn of the century, and the Internet is its crowning achievement, they should not be the only factor determining digital exclusion. Access to the Internet (or any other media) first precedes access to devices, applications and infrastructure, and without them and – what is most important – basic knowledge related to their use, there can be no effective use of the Internet. Therefore, in some of the cited definitions, we also find reference to “soft” causes of digital exclusion (Bartol et al., 2021), including, among others: competences (skills, method of use, etc.) and user motivation (lack of confidence in their own skills, fear of threats, etc.). At the same time, other factors were also indicated, including demographic ones (gender, age, place of residence, etc.).

The lack of one coherent definition of the presented phenomenon has an obvious impact on the difficulty of its measurement. The most common limitations are the availability of statistical data and their comparability in time and space. In the case of the EU, in this respect – following the example of sustainable development or employment and social policy (see Eurostat, n.d.-a) – a set of variables describing the phenomenon of digital exclusion common to all member states is missing. Importantly, the Community promotes the development of ICT technologies and infrastructure (e.g., as part of the Digital Agenda for Europe),

and also emphasizes the need to develop citizens' digital competences (DigComp 2.2, see: Vuorikari et al., 2022). At the same time, as part of Eurostat, the EU has been conducting extensive research on the digital society since 2002, including: as part of The EU survey on the use of Information and Communication Technologies (ICT) in households and by individuals (Eurostat, n.d.-d).

2.2. ICT and the economy, society, environment and sustainable development

In order to explain the source of the links between digital exclusion and sustainable development, it is first necessary to link the second mentioned phenomenon to the concept of ICT (Information and communication technology). According to the Eurostat definition (Eurostat, n.d.-b, n.d.-c), ICT should be understood as all technical means used to process information and support communication, including computer and network hardware and software.

Aghaei and Rezagholizadeh (2020) clearly indicate that, in relation to the OIC (Organization of Islamic Conference) countries, ICT has an impact on their economies (both the demand and supply sides) and stimulates their development. Very similar conclusions can be found in the works: Nasab and Aghaei (2009) (OPEC countries) and Remeikiene et al. (2021) (EU transition economies: Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia). At the same time, there is a clear impact of ICT on the development of human capital, especially through improving the level of education, and thus the use of ICT tools both in everyday life, including state-citizen contacts, and in business (Malaysia Ministry of Economy, n.d.). Additionally, due to its universal nature, connecting citizens, institutions, enterprises, etc., creating a supranational sphere for the exchange of information and ideas (Al-Busaidi, 2014).

As indicated by the World Bank (2013), the development of the ICT sector directly affects the labor market by creating new jobs, while simultaneously increasing the level of innovation and inclusiveness of the economy. A similar conclusion can be found in the works (Aghaei & Rezagholizadeh, 2020; Generation, n.d.) and in the OECD report (OECD, 2004). At the same time, the results of research conducted by this organization indicate that it significantly affects the development of those sectors that are strongly based on ICT technologies, especially the services sector. Products and services created by the ICT sector are also largely responsible for increasing labor productivity and resource efficiency. As noted by (Neffati, 2012), due to the rapid development of new technologies, both in terms of hardware and software, the ICT sector is one of the foundations responsible for the innovativeness of the economy, as well as its important element building its competitiveness.

As already mentioned, ICT technologies affect not only the supply side of the economy, but also, by shaping human behavior, the demand side. This is achieved, for example, through: wide access to new educational techniques, ease of promoting new products and services, access to a wide base of potential customers, an open and global labor market (Bostech ICT Solutions, 2019).

The impact of ICT on the climate and the natural environment is also undeniable. The increasing demand for new advanced products, on the one hand, affects the demand for raw materials and the increase in energy consumption (Reyes et al., 2024; Sustainability Knowledge

Group, 2022). On the other hand, it should not be forgotten that by using appropriate tools, it also supports its protection and ensures the necessary monitoring (ITU, 2008).

Due to the broad impact of ICT technologies on the economy, society and environment, it has an obvious impact on the speed of achieving SDGs. Table 1 presents selected scientific works on this topic along with the conclusions drawn from them.

Table 1. Selected scientific works on the impact of ICT on sustainable development (source: own elaboration)

Article	Conclusions
Nchofoung and Asongu (2022)	ICT has significant and positive impact on sustainable development. Its strength depends on, among others: the geographical location and the income level.
Goswami (2014)	ICT sector important role in green economy (design and its application) and society by fostering transformations, increasing efficiency and reducing divides (economic, social and digital).
Hilty and Hercheui (2010)	ICT supports the development of underdeveloped regions of the world. It can contribute to their sustainable development by providing appropriate tools to support education.
Tjoa and Tjoa (2016)	The impacts of ICT on sustainability development: negative – generation of electronic waste; positive – more efficient resource usage, easier access to education, more efficient business operations.
Henry (2012)	ICT effectively supports countries and companies in the transformation process towards a more sustainable economy.
Jayaprakash and Radhakrishna Pillai (2022)	ICT has a strong impact on improving economic efficiency, which translates into achieving SDGs, including environmental and social aspects.

Analyzing the above works, we can indicate several potential directions of the impact of the digital exclusion phenomenon on society, the economy and the environment:

1. Weakening the potential of society – citizens who do not use modern forms of communication are deprived of access to reliable and impartial information, which may make them susceptible to various forms of disinformation. The phenomenon of digital exclusion may also be associated with a decrease in the potential productivity of the workforce.
2. Weakening the potential of the economy – the lack of access to e-commerce tools by a certain group of citizens directly affects the reduction potential of both the demand and supply base, which in turn has a direct impact on the level of GDP. It also has a negative impact on the innovativeness of the economy and its competitiveness.
3. Negative impact on the natural environment, which refers to the inefficient use of natural resources and the slower dissemination of new technologies, including those enabling the generation of energy from renewable sources, reducing energy consumption and the level of environmental pollution.

The above directions of influence, of course, also directly affect the pace of implementation of SDGs. One of the few works in which the authors undertake a deeper analysis of this phenomenon is (Hidalgo et al., 2020). The authors analyzed data on the digital skills of the Spanish population in order to determine whether training needs in relation to digital

competences affect the level of sustainable development of the country. They pointed to the increasing impact of digital exclusion on socio-economic inequalities and employment opportunities, which is particularly acute in the case of young people.

It should be emphasized, that the literature of the subject also indicates negative aspects of ICT development. For example, Bosamia (2013) points out the following effects:

- reduced face-to-face interaction – resulting from the development of digital communication services;
- social disconnect – physical distancing of people from each other, resulting from replacing real-world contacts with a virtual alternative;
- reduced physical activity/health problems – related to changing habits;
- cost – related primarily to rapid technological progress and the need to keep up with it;
- job loss – resulting from task automation and the development of artificial intelligence;
- security/loss of privacy – on the one hand, the result of collecting more and more information about users and, on the other, the development of a large amount of increasingly complex software and devices, the developers of which do not always want or are able to provide an appropriate level of security.

KeyTech (2023) add to the above list:

- cyberbullying – the use of digital communication to humiliate, harass or intimidate another person;
- technology addiction – excessive dependence on ICT devices and services, negatively affecting human functioning;
- information overload – a wide stream of information generated by the media and transmitted using ICT can cause disinformation, especially due to the recent appearance of a large amount of fake news aimed at causing a specific behavior of certain groups of people;
- environmental impact – the development of ICT causes the generation of a large amount of pollution and waste.

3. Materials and methods

3.1. Characteristics of the research material

The study covered 27 European Union countries, and all data came from Eurostat databases (Eurostat, n.d.-a). The study concerned the year 2023. The choice of this period was dictated, on the one hand, by the desire to use the most up-to-date data, and on the other hand, by the availability and comparability of statistical data for all diagnostic features used in the study. In case of missing data, it was supplemented with the most current values from previous years.

In the analysis of the level of digital exclusion, due to the availability of statistical data, the focus was on three spheres, which are one of the basic determinants of the analyzed phenomenon:

- Internet skills (14 diagnostic features),
- computer skills (9 diagnostic features),
- level of ICT network development (4 diagnostic features).

The first two groups of features related directly to the digital competences of citizens of Member States, while the third group supplemented the analysis with information about their technical potential. The statistical data used for the three groups come from the ICT survey (EU survey on the use of Information and Communication Technologies (ICT) in households and by individuals) (Eurostat, n.d.-e, 2024a, 2024b, 2025a, 2025b, 2025c). The diagnostic features used to describe each sphere are listed in Appendix Table A1.

In the analysis of the impact of the digital divide on the implementation of the SDGs, it was decided to select five out of seventeen goals (United Nations, 2023). The reason for limiting their number was the desire to analyze only those goals that are related to the analyzed phenomenon. These included:

- SDG 4 – quality education,
- SDG 8 – decent work and economic growth,
- SDG 9 – industry, innovation and infrastructure,
- SDG 10 – reduced inequalities,
- SDG 12 – responsible consumption and production.

The sets of diagnostic features used to describe individual goals, were taken from Eurostat Sustainable Development Goals Database (Eurostat, 2025d) and are presented in Appendix Table A2.

Nine synthetic measures were built based on the sets of diagnostic features listed in Appendix Tables A1–A2. Four of them were related to the description of the phenomenon of digital divide and concerned:

- Z1 – Internet skills,
- Z2 – computer skills,
- Z3 – level of ICT infrastructure,
- \bar{Z} – digital exclusion level (average value of Z1, Z2 and Z3 meters).

A high value of the \bar{Z} measure will indicate a low level of digital exclusion in a given EU country.

The next five were related to the assessment of the degree of implementation of selected SDGs:

- Z_SDG 4,
- Z_SDG 8,
- Z_SDG 9,
- Z_SDG 10,
- Z_SDG 12.

3.2. Research method

Analyzing phenomena that cannot be described using a single feature (variable) requires tools and methods that capture their multidimensional nature. One group of such methods is linear ordering methods, which belong to the family of multivariate comparative analysis methods. They are based on the concept of a synthetic measure, the construction of which uses a normalized/standardized set of diagnostic features. This group of methods includes: TOPSIS, Grey Relational Analysis (GRA), Principle Component Analysis (PCA), COPRAS, and Hellwig's taxonomic development measure. Analyses of the above methods, which can be

found in the literature of the subject (e.g., (A. Bąk, 2018; Özcan & Çelik, 2021; Sultana & Dhar, 2020), show that the results obtained using them are comparable in most cases, and the selected standardization/normalization method has the greatest impact on the obtained results. For this reason, the TOPSIS method, which has an established position in the literature of the subject, was used in this work.

The TOPSIS method (Technique for Order Preference by Similarity to an Ideal Solution) was used to construct synthetic measures. This method, derived from MDNA (multi-criteria decision analysis techniques) (Hwang & Yoon, 1981), is successfully used for the statistical classification of objects described by large number of statistical features (multivariate statistical analysis) (Bąk et al., 2022; Chatterjee & Lim, 2022; Dmytrów, 2018; Hezer et al., 2021; Roszko-Wójtowicz & Grzelak, 2019). In th method, based on a set of diagnostic features, two synthetic objects called a pattern (Positive Ideal Solution) and an anti-pattern (Negative Ideal Solution) are determined. Then, in next step, the distances from each of the analyzed objects are calculated. In such a case, the object closest to the pattern and farthest from the anti-pattern is considered optimal. The TOPSIS method calculation procedure includes six steps:

1. Assigning weights for individual diagnostic features. They should meet the following condition:

$$\sum_{k=1}^j w_k = 1. \quad (1)$$

In a situation where discrimination of individual diagnostic features or groups thereof is not required, it is possible to assign equal weight to all of them as 1.

2. Bringing the set of diagnostic features to comparability.

The zeroed unitarization method was used in process of data normalization, according to the following equation (Kryk & Guzowska, 2021; Kukuła & Bogocz, 2014):

$$m_{ik} = \begin{cases} w_k \cdot \frac{x_{ik} - \min x_k}{\max x_k - \min x_k} & \text{for stimulants} \\ w_k \cdot \frac{\max x_{ik} - x_k}{\max x_k - \min x_k} & \text{for destimulats} \end{cases}, \quad (2)$$

where: w_k – weight assigned to the k -th feature, $\min x_k$ – minimum value of the k -th feature $\max x_k$ – maximum value of the k -th feature.

3. Determining the coordinates of the pattern and anti-pattern.

Unlike the classic TOPSIS method, where normalization or standardization was used to make features comparable, the use of the zero-based unitarization method simplifies the determination of pattern and anti-pattern coordinates. This is due to the fact that for features subjected to such a procedure, their normalized values are in the range [0,1], with the value 0 being given to the worst object in terms of the adopted criterion, and 1 to the best one. This means that the coordinates of the pattern and anti-pattern e constant for all diagnostic features and are:

$$m_k^{*+} = 1; \quad (3)$$

$$m_k^{*-} = 0, \quad (4)$$

where: m_k^+ – k -th coordinate of Positive Ideal Solution, m_k^- – k -th coordinate of Negative Ideal Solution.

4. Determining the distance of objects analyzed from the pattern and anti-pattern. The Euclidean distance was used:

$$d_i^+ = \sqrt{\sum_{k=1}^j (m_{ik} - m_k^{*+})^2} = \sqrt{\sum_{k=1}^j (m_{ik} - 1)^2}; \quad (5)$$

$$d_i^- = \sqrt{\sum_{k=1}^j (m_{ik} - m_k^{*-})^2} = \sqrt{\sum_{k=1}^j (m_{ik})^2}, \quad (6)$$

where: d_i^+ – distance between i -th object and Positive Ideal Solution, d_i^- – distance between i -th object and Negative Ideal Solution.

5. Determining, based on the distance from the pattern and anti-pattern, the value of the synthetic meter (M) for individual objects:

$$M_i = \frac{d_i^-}{d_i^- + d_i^+}. \quad (7)$$

6. Classification of objects into typological groups based on the value of the synthetic measure:

$$\text{group 1: } \bar{M} + S_M \leq M_i; \quad (8)$$

$$\text{group 2: } \bar{M} \leq M_i < \bar{M} + S_M; \quad (9)$$

$$\text{group 3: } \bar{M} - S_M \leq M_i < \bar{M}; \quad (10)$$

$$\text{group 3: } M_i < \bar{M} - S_M, \quad (11)$$

where: M_i – value of the synthetic measure for the i -th object, \bar{M} – average value of the synthetic measure, S_M – standard deviation of the synthetic measure.

4. Results

4.1. Digital exclusion in EU countries in 2023

Table 2 presents the values of four synthetic measures describing: Z1 – level of Internet skills, Z2 – level of computer skills, Z3 – level of ICT infrastructure and \bar{Z} – level of digital exclusion. The value of the last one mentioned is the average value of the three previous ones, and its low level indicates a high intensity of the phenomenon under study in a given EU country.

Analyzing the information on the synthetic measures included in Table 2, it can be noticed that their average values for 2023 differed only slightly (by a maximum of 0.096) and amounted to: 0.492, 0.530 and 0.588, respectively. At the same time, a high level of the coefficient of variation, exceeding 18%, was recorded for all measures. This means that citizens of EU countries differ in terms of both the level of Internet and computer skills as well as the level of telecommunications infrastructure. This fact is also emphasized by the high range value of 0.627, 0.913 and 0.440, respectively.

Table 2. Values of synthetic Z1, Z2, Z3 and \bar{Z} measures, ranks and typological groups in EU countries (source: own elaboration)

Country	Z1	Ranks	Groups	Z2	Ranks	Groups	Z3	Ranks	Gros	\bar{Z}	Ranks	Groups
Belgium	0.492	14	2	0.539	13	2	0.655	10	2	0.562	13	2
Bulgaria	0.177	27	4	0.105	26	4	0.473	24	4	0.252	27	4
Czechia	0.515	12	2	0.588	12	2	0.658	8	2	0.587	11	2
Denmark	0.768	3	1	0.700	4	2	0.697	5	2	0.722	3	1
Germany	0.300	24	4	0.498	15	3	0.625	13			17	3
Estonia	0.623	7	2	0.665	7	2	0.703	3	1	0.664	6	2
Ireland	0.637	6	2	0.779	3	1	0.566	14			7	2
Greece	0.332	23	3	0.393	22	3	0.492	23	3	0.406	23	3
Spain	0.616	9	2	0.657	8	2	0.773	2			4	1
France	0.395	18	3	0.590	11	2	0.501	22	3	0.495	15	3
Croatia	0.367	21	3	0.470	18	3	0.506	21	3	0.448	19	3
Italy	0.352	22	3	0.472	16	3	0.454	25	4	0.426	22	3
Cyprus	0.518	11	2	0.538	14	2	0.546	16	3	0.534	14	3
Latvia	0.483	15	3	0.311	25	4	0.351	27	4	0.382	25	4
Lithuania	0.492	13	2	0.419	20	3	0.397	26			20	3
Luxembourg	0.468	16	3	0.626	10	2	0.701	4	1	0.598	10	2
Hungary	0.619	8	2	0.472	17	3	0.647	11	2	0.579	12	2
Malta	0.647	5	2	0.633	9	2	0.695	6	2	0.658	8	2
Netherlands	0.777	2	1	0.915	2	1	0.791	1	1	0.828	1	1
Austria	0.540	10	2	0.673	6	2	0.666	7	2	0.626	9	2
Poland	0.280	25	4	0.391	23	3	0.522	19	3	0.398	24	3
Portugal	0.425	17	3	0.454	19	3	0.521	20	3	0.467	18	3
Romania	0.223	26	4	0.016	27	4	0.539	17	3	0.259	26	4
Slovenia	0.392	19	3	0.414	21	3	0.656	9	2	0.487	16	3
Slovakia	0.369	20	3	0.371	24	3	0.560	15	3	0.433	21	3
Finland	0.804	1	1	0.929	1	1	0.533	18	3	0.755	2	1
Sweden	0.673	4	1	0.692	5	2	0.640	12	2	0.669	5	2
\bar{x}	0.492			0.530			0.588			0.537		
$S(x)$	0.165			0.202			0.108			0.142		
$V_s [\%]$	33.610			38.180			18.419			26.369		
min	0.177			0.016			0.351			0.252		
max	0.804			0.929			0.791			0.828		
R	0.627			0.913			0.440			0.576		
Skew	0.116			-0.386			-0.156			-0.059		

The distributions of the Z2 and Z3 measures are characterized by left-sided asymmetry (the skewness for Z2: -0.386 and for Z3: -0.156), meaning a predominance of objects with values higher than the average value, and for the Z1 measure there is right-sides asymmetry (skewness = 0.116). Values lower than the average value were recorded for the following measures: Z1, Z2 for 13 countries and Z3 for 14 countries.

The highest level in the case of the first two measures was recorded for Finland (Z1: 0.804, Z2: 0.929). The group with the highest levels (typological group 1) included, in addition to the above-mentioned Finland, also Netherlands, which in the case of Z1 is complemented by Denmark and Sweden and Z2 by Ireland. In the case of the measure relating to infrastructure (Z3), its highest level was recorded for the Netherlands (0.791). The first group also included: Spain, Estonia and Luxembourg.

In turn, the lowest levels of synthetic measures were recorded for Buaria (Z1: 0.177), Romania (Z2: 0.016) and Latvia (Z3: 0.351), respectively. Typological group 4 also includes, in the case of the Z1 measure: Germany, Poland and Romania; Z2: Latvia and Bulgaria and Z3: Bulgaria, Italy and Lithuania.

The analysis of the average values of diagnostic features for the best (1) and worst (4) typological groups (Figure 1) shows that the greatest differences are visible in the sets of indicators constituting the basis for the construction of the first two measures. In the case of the Z1 measure, the highest differences between average values were recorded for the following features: Internet banking (X1.7; by 52.17 p.p.), finding information about goods and services (X1.5; by 39.47 p.p.), sending/receiving e-mails (X1.2; by 34.32 p.p and online learning material (X1.12; by 31.46 p.p.).

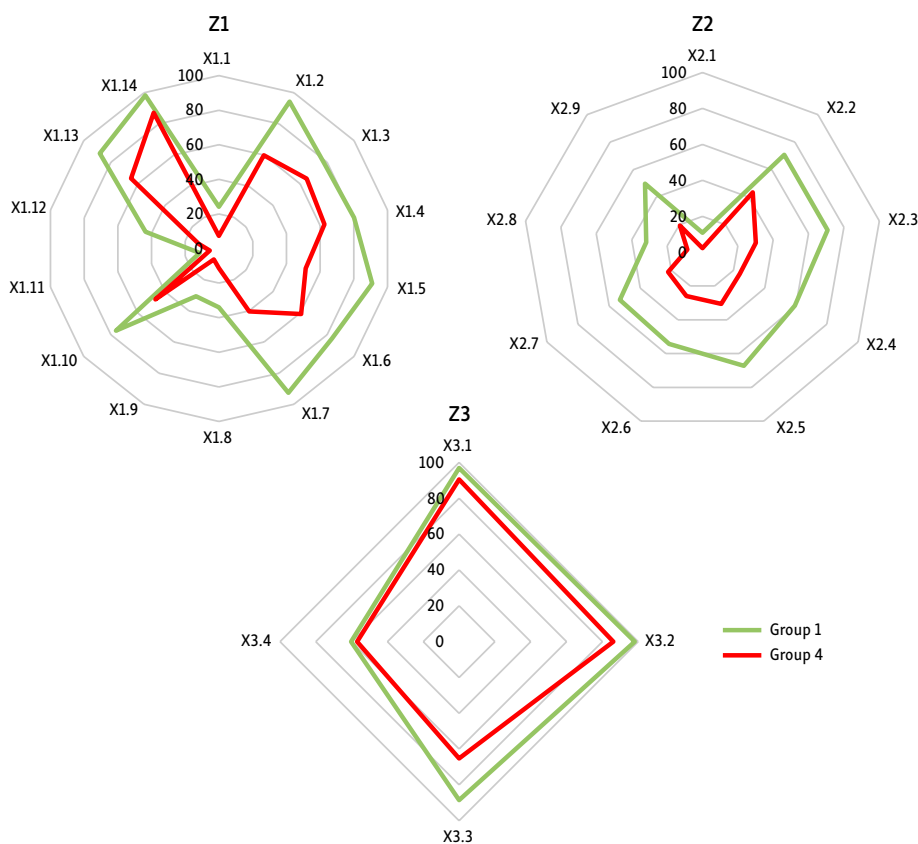


Figure 1. Average values of diagnostic features constituting the basis for calculating the Z1, Z2 and Z3 measures according to typological groups 1 and 4 (source: own elaboration)

In turn, in the case of the Z2 measure, high differences between the features characterizing extreme (1 and 4) typological groups were recorded for the following indicators: Individuals who downloaded or installed software or apps (X2.3; by 40.56 p.p.), individuals who used word processing software (X2.5; by 36.65 p.p.), individuals who changed the settings of software, app or device (X2.4; by 35.32 p.p.), individuals who used spreadsheet software (X2.7; by 31 p.p.).

In the case of the Z3 measure, the differences between the feature values were definitely lower than in the case of the first two measures, and the highest were recorded for: household Internet connection – fixed broadband (X3.3; by 23.26 p.p.) and broadband Internet coverage by speed – more than 30 Mbps (X3.2; by 11.98 p.p.).

The analysis of Pearson's linear correlation coefficients between the values of the Z1, Z2, Z3 measures (Table 3) indicates that there is a strong positive relationship between computer (Z1) and Internet (Z2) skills. With the current level of development of Internet services, some applications previously available in stationary form, such as word processors, spreadsheets, or more advanced applications – audio or graphic file editors, increasingly often have fully functional online equivalents.

At the same time, what is worth noting, the strength of the correlation between the Z1 and Z2 measures and Z3 is moderate at best. This may indicate a good level of development of ICT infrastructure in EU countries in 2023, guaranteeing access to network services for citizens of Member States.

The average value of the \bar{Z} measure, indicating the level of digital exclusion in 2023, was 0.537. This value was exceeded by 13 out of 27 EU countries. The highest level of the synthetic measure, and therefore the lowest level of digital exclusion, was recorded for the Netherlands (0.828), which, together with Finland, Denmark and Spain, formed the first typological group.

The lowest value of the average synthetic measure (\bar{Z}), and therefore the highest level of digital exclusion, was recorded for Bulgaria (0.252), which, together with Romania and Latvia, formed the fourth typological group. It is worth emphasizing the high level of difference between the best and the worst country in the classification, amounting to 0.576.

It should be noted that the \bar{Z} measure, which is the resultant of the values of the Z1, Z2 and Z3 measures, was characterized by high variability ($V_s = 26.4\%$) and almost symmetrical distribution (-0.059).

Figures 2–5 show the spatial distribution of EU countries in terms of the values of the analyzed synthetic measures Z1, Z2, Z3 and \bar{Z} . There are differences between EU countries depending on the studied phenomena. High ratings for the analyzed measures were recorded primarily for Northern European countries and Spain. The countries of the Balkan Peninsula (Romania and Bulgaria) and Poland stood out negatively in this respect.

Table 3. Pearson's linear correlation coefficient values between the values of synthetic measures Z1, Z2 and Z3 (Source: own elaboration)

Measure	Z1	Z2	Z3
Z1	1.000	0.854*	0.523*
Z2	0.854*	1.000	0.554*
Z3	0.523*	0.554*	1.000

Note: * statistically significant at $\alpha = 0,05$.

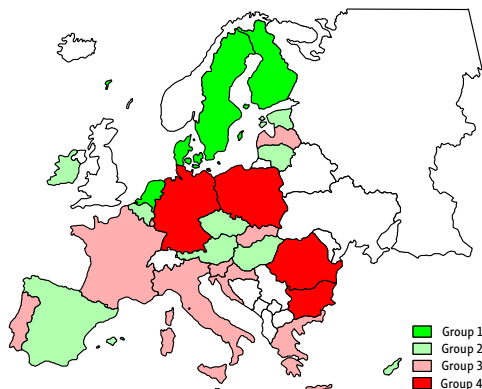


Figure 2. EU countries according to the Z1 measure (source: own elaboration)

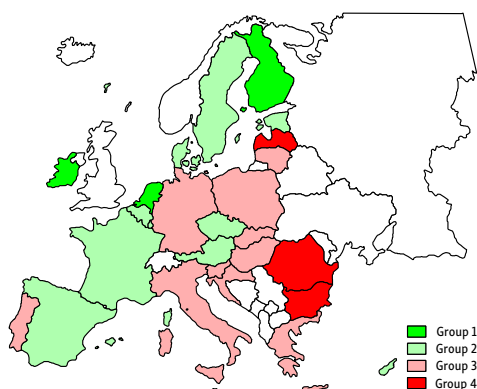


Figure 3. EU countries according to the Z2 measure (source: own elaboration)

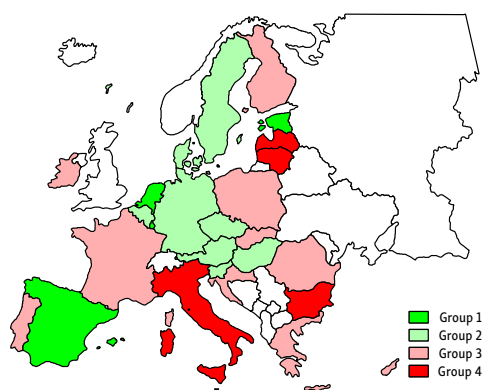


Figure 4. EU countries according to the Z3 measure (source: own elaboration)

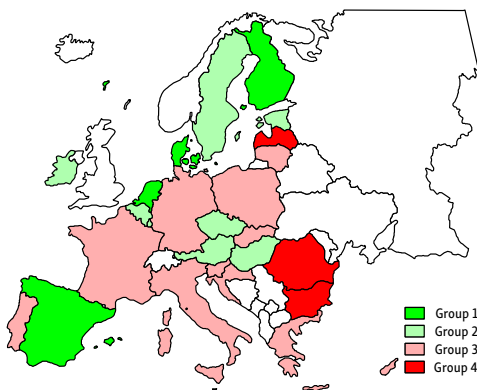


Figure 5. EU countries according to the Z measure (source: own elaboration)

4.2. Levels of implementation of selected sustainable development goals in EU countries in 2023

To assess the impact of digital divide on the implementation of the Ss, using data provided by Eurostat, synthetic measures were constructed for 2023, indicating the level of their implementation for 5 out of 17 goals:

- SDG 4 – quality education,
- SDG 8 – decent work and economic growth,
- SDG 9 – industry, innovation and infrastructure,
- SDG 10 – reduced inequalities,
- SGD 12 – responsible consumption and production.

They are presented in Table 4.

The average values of individual synthetic measures and coefficients of variation ranging from 11.81% (Z_SDG12) to 24.46% (Z_SDG4) indicate a large diversity of EU countries in terms of the studied areas of sustainable development.

Table 4. Values of synthetic measures for five selected SDGs (4, 8, 9, 10 and 12) by EU countries for 2023 (source: own elaboration)

Country	SDG 4		SDG 8		SDG 9		SDG 10		SDG 12	
	Z_SDG4	Ranks	Z_SDG8	Ranks	Z_SDG9	Ranks	Z_SDG10	Ranks	Z_SDG12	Ranks
Belgium	0.646	7	0.661	5	0.648	6	0.670	7	0.524	6
Bulgaria	0.243	26	0.457	23	0.441	22	0.391	26	0.397	24
Czechia	0.582	17	0.692	4	0.462	18	0.726	3	0.467	16
Denmark	0.728	3	0.722	3	0.678	5	0.670	6	0.527	4
Germany	0.510	21	0.653	7	0.596	8	0.655	11	0.490	11
Estonia	0.697	5	0.588	12	0.516	10	0.446	25	0.394	26
Ireland	0.750	1	0.656	6	0.507	11	0.752	2	0.500	9
Greece	0.397	24	0.413	27	0.407	26	0.455	23	0.505	8
Spain	0.611	13	0.454	24	0.496	13	0.457	22	0.499	10
France	0.644	8	0.560	18	0.540	9	0.607		0.532	3
Croatia	0.559	18	0.527	22	0.422	24	0.526	19	0.464	17
Italy	0.508	22	0.425	26	0.447	21	0.484	20	0.564	2
Cyprus	0.374	25	0.573	14	0.422	25	0.554	17	0.394	25
Latvia	0.606	15	0.548	19	0.479	15	0.447	24	0.464	18
Lithuania	0.636	10	0.565	15	0.492	14	0.462	21	0.456	20
Luxembourg	0.639	9	0.538	21	0.622	7	0.626	12	0.337	27
Hungary	0.511	20	0.650	8	0.476	17	0.574	15	0.462	19
Malta	0.527	19	0.579	13	0.436	23	0.558	16	0.490	12
Netherlands	0.697	4	0.728	2	0.701	2	0.775	1	0.599	1
Austria	0.621	12	0.608	11	0.690	3	0.665	9	0.526	5
Poland	0.610	14	0.563	16	0.478	16	0.656	10	0.447	21
Portugal	0.597	16	0.547	20	0.401	27	0.540	18	0.509	7
Romania	0.169	27	0.446	25	0.452	20	0.353	27	0.467	14
Slovenia	0.622	11	0.627	9	0.505	12	0.709	4	0.427	22
Slovakia	0.461	23	0.561	17	0.456	19	0.620	13	0.484	13
Finland	0.669	6	0.622	10	0.682	4	0.699	5	0.410	23
Sweden	0.744	2	0.738	1	0.768	1	0.665	8	0.467	15
\bar{x}	0.569		0.581		0.527		0.583		0.474	
$S(x)$	0.139		0.089		0.104		0.114		0.056	
$V_s [\%]$	24.455		15.370		19.675		19.492		11.805	
min	0.169		0.413		0.401		0.353		0.337	
max	0.750		0.738		0.768		0.775		0.599	
R	0.581		0.325		0.367		0.422		0.262	
Skew	-1.319		-0.139		0.865		-0.261		-0.238	

The highest levels of the synthetic measure were recorded for: Ireland (Z_SDG4 – 0.750), Sweden (Z_SDG: 8 – 0.738 and 9 – 0.768) and the Netherlands (Z_SDG: 10 – 0.775 and 12 – 0.599). In turn, the lowest values were recorded for Romania (Z_SDG: 4 – 0.169, 10 – 0.353), Greece (Z_SDG8 – 0.413), Portugal (Z_SDG9 – 0.401) and Luxembourg (Z_SDG12 – 0.337).

Based on the values of synthetic measures presented in Tables 2 and 4, the values of Pearson's linear correlation coefficients were calculated. The results were presented in Table 5.

Moving on to the analysis of the relationship between synthetic measures describing the level of digital divide (\bar{Z}) and selected SDGs (Table 5), it should be noted that all values of the correlation coefficients are positive and indicate a moderate strength of the relationship.

Table 5. Pearson's linear correlation coefficient values between synthetic measures describing the level of digital divide and SDGs (source: own elaboration)

Variable	Z_SDG4	Z_SDG8	Z_SDG9	Z_SDG10	Z_SDG12
Z1	0.680*	0.638*	0.567*	0.473*	0.151
Z2	0.779*	0.602*	0.621*	0.677*	0.213
Z3	0.340	0.482*	0.475*	0.463*	0.105
\bar{Z}	0.723*	0.659*	0.638*	0.625*	0.187

Note: * statistically significant at $\alpha = 0,05$.

However, it should be emphasized that there were differences in their levels, especially for SDG 4 (quality education) and SDG 12 (responsible consumption and production). They were higher (compared to SDG 4) or lower (compared to SDG 12) than for the goals: SDG 8 (decent work and economic growth), SDG 9 (industry, innovation and infrastructure) and SDG 10 (reduced inequalities), for which they approached the value of 0.65.

The values of the correlation coefficients of the Z3 measure with the measures related to the implementation of the SDGs are also worth noting; the strength of the relationship should be considered low in the case of SDG 12 (0.187) and moderate for the others.

Figure 6 presents scatterplots between the values of measures describing the degree of implementation of SDGs and the level of digital exclusion \bar{Z} .

The analysis of the information contained in Figure 6 shows that the spreads of points in all cases are (more or less) similar. Two countries that clearly lag behind in terms of the value of synthetic measures are Bulgaria and Romania. The remaining EU countries form a larger group, including the following countries: the Netherlands, Denmark, Finland, Sweden, Austria, Luxembourg and Ireland. They clearly lead in terms of both the level of implementation of individual goals and the low level of digital exclusion.

5. Discussion

5.1. Digital divide and spatial distribution of EU countries

The presented results (Table 2, Figures 2–5) suggest that EU countries differ in terms of the level of digital exclusion. Analyzing carefully the information on the value of the \bar{Z} measure, it should be noted that among the countries that joined this organization after 2004, 11 (out of 13) were classified into typological groups 3 and 4. Northern European countries are at the forefront. This suggests that the level of digital exclusion may be influenced by the level of economic development, and this is confirmed by the value of the Pearson linear correlation coefficient between the synthetic measure \bar{Z} and the value of real GDP per capita in 2023, amounting to 0.565 and indicating a moderate positive relationship. Similar conclusions can

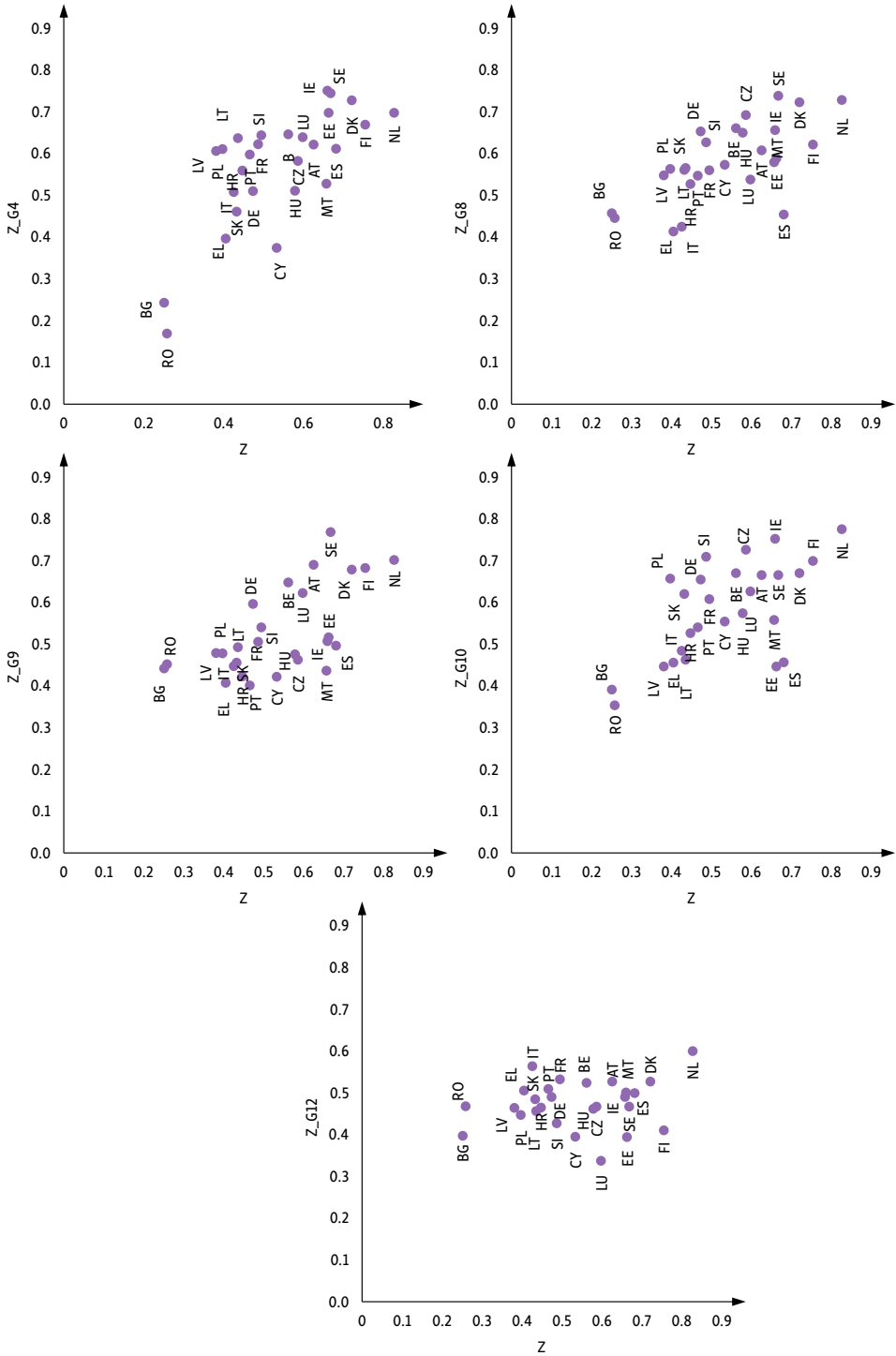


Figure 6. Scatterplots of the values of synthetic measures for selected SDGs against \bar{Z} measure (source: own elaboration)

also be found in the results of research conducted by other authors. As Steele (2018) points out, a low level of digital divide increases productivity and influences the development of new industries and sectors based on communication. IEEE (2023) and Townsend (2020) suggest that the level of digital divide directly affects the wealth of society and the quality of human capital. Kituyi (2018) emphasizes that the phenomenon of digital exclusion will affect the speed of development of the global digital economy and the integration of developing countries within it. In turn, the Deloitte report (2021) clearly shows that both the greater availability of broadband connections and their greater capacity promote the creation of new jobs in the USA. However, it should also be emphasized that previous research, e.g., (Wheeler et al., 2001), does not indicate a direct impact of economic development on the level of digital exclusion, but rather on the nature of state policy.

5.2. Digital divide and differences between EU countries

An in-depth analysis of the results presented in Figure 1 indicates several important reasons for the differences between individual countries in terms of the level of digital exclusion:

- An important factor discriminating the analyzed group of countries in the context of Internet skills (Z1 measure) was online banking services (X1.7). This may suggest problems with the development of this type of services in individual countries, although they are not related to a lack of skills or infrastructure problems, but rather to the difficulty of changing customer habits or security concerns (Mitham, 2021). Legal regulations of individual member states regarding the use of electronic banking tools by financial institutions are also important in this respect.
- The large differences between the first and fourth typological groups of countries in terms of using the Internet to search for information on products and services (X1.5), as well as on health (X1.10), should be associated with the development of society, its level of wealth and conscious consumption decision making (see Chen et al., 2021).
- Differences in the average levels of diagnostic features related to computer skills (Z2 measure) can be partly explained by their nature. For example, referring to diagnostic feature X2.4 (the Individuals who changed the settings of software, app or device) – installed applications are ready to run without the need for their configuration, which is usually carried out rarely, only when it is necessary for their proper operation. On the other hand, frequent configuration of devices may be caused by their frequent replacement. Taking into account the entire world, the life cycle of a smartphone was 3.7 years in 2022. This means that, on average, it was replaced after this period. However, over 40% of users replace it more often, at most every 2–3 years (Knight, 2024). This should be read as the desire to remain “up-to-date”, giving the opportunity to use all technological innovations.
- Indirectly results from Figure 1 is the fact that clearly higher levels of average diagnostic features were recorded for the set constituting the basis for the construction of the Z1 meter, i.e., referring to the ability to use the Internet. This means that the respondents of the ICT survey, which is the source of data in this study, are much better at using the Internet and related services than at using a computer. What is worth emphasizing,

for most people, both activities are the same, even though they cover a completely different scope of activities and related productivity. However, low levels of computer skills are a problem that is not unique to Europe (Nielsen, 2016).

5.3. ICT infrastructure and sustainable development

Also noteworthy are the values of correlation coefficients between the Z3 measure, describing the level of ICT infrastructure in EU countries, and the other calculated measures (Table 5). They suggest the existence of at most a moderate relationship between the analyzed variables. This may indicate a high level of infrastructure development, which is confirmed by the X3.1 feature (households – level of internet access), the average value of which for all EU countries in 2023 was 93.05%, with the minimum value of 86.9% recorded for Greece. As highlighted in the report (ITU, 2021), Europe is a leader in the world in the context of infrastructure development, especially IoT (Internet of Things) and cloud services. At the same time, the period of the COVID-19 pandemic proved how well ICT service operators operating on the old continent were prepared for a significant increase in demand for connection capacity. In turn, (Toader et al., 2018) indicated in their work that the condition of infrastructure and its level of development directly influenced the speed of economic development of EU countries.

Analyzing the values of the correlation coefficients between the \bar{Z} measure and measures describing the level of implementation of the SDGs, we can notice that in the case of the goals: SDG 4 (quality education) and SDG 12 (responsible consumption), their levels were different than for the others. In the case of the former, this may be due to the fact that it refers primarily to young people who acquire ICT skills primarily through self-education (Penjor et al., 2016). According to the Polish EU Kids Online 2018 Study (Pyżalski et al., 2019), as many as 40% of respondents used the Internet for up to 2 hours on weekdays and up to 3 hours on weekends, and 19% of respondents used the Internet for more than 6 hours on weekends. This means that their education in subjects at various levels, despite a well-prepared teaching base (Lindfors, 2007; Trucano, 2013), does not significantly affect the level of digital exclusion. In turn, the impact of this phenomenon on the level of sustainable consumption (SDG 12) is limited primarily due to the fact that it is determined by other factors (Rizkalla, 2018) that have a stronger impact. In the case of the following goals: SDG 8 (decent work and economic growth), SDG 9 (industry, innovation and infrastructure) and SDG 10 (reduced inequalities), the impact of the analyzed phenomenon is stronger, and this is due to the previously mentioned impact on the quality of human capital (Blessinger et al., 2022; Payab et al., 2023).

6. Conclusions

This work shows that EU countries in 2023 were diverse in terms of the level of digital exclusion. It was noticeable both in the area of Internet and computer skills and in the level of ICT infrastructure, especially between the “new” (adopted after 2004) and the “old” Member States. At the same time, large differences were also noted in the levels of implementation of the five selected SDGs. The analysis of the correlation between synthetic measures describing

the phenomenon of digital divide and the level of implementation of the SDGs indicated the existence of a moderate relationship between them. However, the range of values of the obtained Pearson correlation coefficients suggests different strengths of their mutual connections. This means that research hypothesis H1 and H2 were positively validated.

It is important to emphasize the differences between the countries of Northern Europe and the rest of the continent. Countries such as the Netherlands, Finland, Denmark, Sweden, in addition to a high level of socio-economic development (see e.g., Human Development Index (United Nations Development Programme [UNDP], 2022)), are also those whose economies are largely knowledge-based (I. Bąk et al., 2022). Hence the high level of digital competences of their citizens. Other countries, especially those that joined the community recently (Romania Bulgaria), should focus on appropriate IT education, aimed primarily at encouraging citizens to develop their acquired skills independently. At the same time, it should start as early as possible – initially in the form of games (e.g., programming, automation and robotics courses for children), moving on to appropriately constructed curricula in schools and universities. These subjects should be taught in such a way, that students could see the possibility of applying the knowledge they have acquired, and not just learn “dry facts”.

A noteworthy conclusion from the conducted analyzes is that the level of development of ICT infrastructure in EU countries is so high that it is no longer a factor determining the level of digital exclusion, nor is it a factor inhibiting the process of achieving the SDGs. This is undoubtedly the result of long-term actions undertaken by the Member States and the entire EU, and proof of the validity of the assumptions regarding the directions of development already made in the Lisbon Strategy in 2000 (European Parliament, 2004). Based on the result, it can be stated that, research hypothesis H3 was positively validated only to goals: SDG8, SDG9 and SDG10. For the remaining goals, the research results indicate a low correlation between the level of development of ICT infrastructure and level of implementation of SDGs.

It should also be emphasized that rapid technological development, especially in the last twenty years, has made the functioning of both society and the economy dependent on the appropriate level of development of the ICT infrastructure, access of residents to devices (understood in both physical and economic terms), as well as the appropriate level of skills of people who can use it. According to the author, in the case of such deeply integrated entities as the EU, actions aimed at eliminating the digital gap should be – and most importantly – are taken, both at the level of the entire Union and individual countries. The Digital Europe Programme (European Commission, 2025b) or the Digital Decade policy programme (European Commission, 2025a) should be mentioned here. These programmes are to ensure not only a high level and quality of technical infrastructure, but also to strengthen human capital and prepare appropriate legal solutions to the rapidly changing digital economy. However, the speed of implementation and effectiveness of the aforementioned programmes will depend on decisions taken at the level of individual countries. Unfortunately, the fight against the phenomenon of digital exclusion, compared to other problems of recent years, such as the COVID-19 pandemic, the war in Ukraine, or energy security problems, is currently not a high priority. Therefore, which is also the indirect goal of this work, it is necessary to emphasize and indicate to the EU institutions and member states the fact of the multidimensional negative impact of the analyzed phenomenon.

We are witnessing a revolution in the form of technologies related to artificial intelligence. The European Union is facing a great opportunity, which, if properly used, may allow it to become one of the leading entities in this field. At the same time, it cannot afford – as in the case of the semiconductor revolution at the turn of the 20th and 21st, or the development of the industry related to the production of green energy – “to give up this match by walkover”, because it would mean complete dependence on external solutions, e.g., from the USA, Japan or China. According to the author, the time has come to fully exploit the potential of the countries of the Community, hidden in their knowledge-based economies. On the one hand, this will certainly deepen the integration between members, but it will also stimulate their socio-economic development.

Some limitations of this work should also be noted. Firstly, the selected period of analysis, which covered the time of the COVID-19 pandemic. This period undoubtedly favored the development of ICT services, clearly accelerating the digital transformation of many sectors. At the same time, it highlighted, among others: the problem of digital divide (Cheshmehzangi et al., 2023). The pandemic also had a multi-vector impact on the implementation of the SDGs (Lekagul et al., 2022; Yuan et al., 2023). Therefore, it would also be worth conducting an analysis of earlier periods. Secondly, narrowing the analysis period to one year made it impossible to analyze the impact of the time factor, both on the level of digital divide in EU countries and its impact on the implementation of SDGs. Of particular interest in this context would be an analysis of the differences between the “new” and “old” Member States. Additionally, an interesting direction for further research would also be to analyze the causes of significant differences in the level of digital exclusion between Northern European countries and the rest of the continent.

It should be emphasized, however, that such a selection of the analysis period made it possible, on the one hand, to ensure that the statistical data is as up-to-date as possible and, on the other hand, to maintain comparability for a wide group of features describing the analyzed spheres of the digital divide phenomenon. This is very important, especially considering the frequent changes in the scope of The EU survey on the use of Information and Communication Technologies (ICT) in households and by individuals, conducted by Eurostat and which is the source of data for this study.

Funding

The publication was funded by the Faculty of Economics, West Pomeranian University of Technology in Szczecin within The International Center for Inclusive Economic Development (IDEAL).

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APPENDIX

Table A1. A set of features describing three spheres related to the phenomenon of digital divide
(Source: Eurostat , 2024b, 2024a, 2025a, 2025b 2025c)

Symbol	Feature name	Unit	Properties
Internet skills			
X1.1	Internet use: doing an online course (of any subject)	% of individuals	stimulant
X1.2	Internet use: sending/receiving e-mails	% of individuals	stimulant
X1.3	Internet use: telephoning or video calls	% of individuals	stimulant
X1.4	Internet use: participating in social networks	% of individuals	stimulant
X1.5	Internet use: finding information about goods and services	% of individuals	stimulant
X1.6	Internet use: reading online news sites/newspapers/news magazines	% of individuals	stimulant
X1.7	Internet use: Internet banking	% of individuals	stimulant
X1.8	Internet use: selling goods or services	% of individuals	stimulant
X1.9	Internet use: job search or sending an application	% of individuals	stimulant
X1.10	Internet use: seeking health information	% of individuals	stimulant
X1.11	Internet use: taking part in on-line consultations or voting to define civic or political issues	% of individuals	stimulant
X1.12	Internet use: online learning material	% of individuals	stimulant
X1.13	Internet use: instant messaging	% of individuals	stimulant
X1.14	Last internet use in last 3 months	% of individuals	stimulant
Computer skills			
X2.1	Individuals who have written code in a programming language (3 months)	% of individuals	stimulant
X2.2	Individuals who have copied or moved files between folders, devices or on the cloud (3 months)	% of individuals	stimulant
X2.3	Individuals who downloaded or installed software or apps (3 months)	% of individuals	stimulant
X2.4	Individuals who changed the settings of software, app or device (3 months)	% of individuals	stimulant
X2.5	Individuals who used word processing software (3 months)	% of individuals	stimulant
X2.6	Individuals who have created files integrating elements such as text, pictures, tables, charts, animations or sound (3 months)	% of individuals	stimulant
X2.7	Individuals who used spreadsheet software (3 months)	% of individuals	stimulant
X2.8	Individuals who used advanced features of spreadsheet software to organise, analyse, structure or modify data (3 months)	% of individuals	stimulant
X2.9	Individuals who edited photos, video or audio files (3 months)	% of individuals	stimulant
ICT infrastructure			
X3.1	Households - level of internet access	% of households	stimulant
X3.2	Broadband internet coverage by speed - more than 30 Mbps	% of households	stimulant
X3.3	Household internet connection - fixed broadband	% of households	stimulant
X3.4	Household internet connection - mobile broadband	% of households	stimulant

Table A2. Set of features describing selected sustainable development goals (source: Eurostat, 2025d)

Symbol	Feature name	Unit	Properties
Goal 4 – Quality education			
X4.1	Adult participation in learning in the past four weeks	%	stimulant
X4.2	Early leavers from education and training	%	destimulant
X4.3	Low achieving 15-year-olds in reading	%	destimulant
X4.4	Low achieving 15-year-olds in mathematics	%	destimulant
X4.5	Low achieving 15-year-olds in science	%	destimulant
X4.6	Participation in early childhood education	%	stimulant
X4.7	Share of individuals having at least basic digital skill	%	stimulant
X4.8	Tertiary educational attainment	%	stimulant
Goal 8 – Decent work and economic growth			
X5.1	Total employment	% of total population	stimulant
X5.2	Fatal accidents at work	per 100 000 workers	destimulant
X5.3	In work at-risk-of-poverty rate	%	destimulant
X5.4	Investment share of GDP by institutional sectors	%	stimulant
X5.5	Long-term unemployment rate	% of population in the labour force	destimulant
X5.6	Persons outside the labour force due to caring responsibilities	% of total population	destimulant
X5.7	Raw material consumption (RMC)	tonnes per capita	destimulant
X5.8	Real GDP per capita	chain linked volumes (2010), euro per capita	stimulant
X5.9	Young people neither in employment nor in education and training by sex (NEET) [SDG_08_20]	% of total population	destimulant
Goal 9 – Industry, innovation and infrastructure			
X6.1	Gross domestic expenditure on R&D	% of GDP	stimulant
X6.2	R&D personnel by sector	% of population in the labour force (FTE)	stimulant
X6.3	Patent applications to the European Patent Office	per million inhabitants	stimulant
X6.4	Share of buses and trains in inland passenger transport	%	stimulant
X6.5	Share of rail and inland waterways in inland freight transport	%	stimulant
X6.6	Air emission intensity from industry – particulates < 10µm	grams per euro, chain linked volumes (2010)	destimulant
X6.7	Tertiary educational attainment	%	stimulant

End of Table A2

Symbol	Feature name	Unit	Properties
X6.8	Gross value added in environmental goods and services sector	% of GDP	stimulant
X6.9	High-speed internet coverage	% of households	stimulant
Goal 10 – Reduced inequalities			
X7.1	Real expenditure per capita	%	stimulant
X7.2	Adjusted gross disposable income of households per capita	per inhabitant (PPS EU27 2020)	stimulant
X7.3	Relative poverty gap (cut-off point: 60% of median equivalised income)	%	destimulant
X7.4	Income distribution	ratio	destimulant
X7.5	Income share of the bottom 40 % of the population	%	stimulant
X7.6	Asylum applications – first time applicant	per 100 000 inhabitant	destimulant
X7.7	Asylum applications – positive first instance decision	per 100 000 inhabitant	destimulant
X7.8	People at risk of poverty or social exclusion – cities	%	destimulant
X7.9	People at risk of poverty or social exclusion – towns and suburbs	%	destimulant
X7.10	People at risk of poverty or social exclusion – rural areas	%	destimulant
X7.11	Persons at risk of monetary poverty after social transfers	%	destimulant
X7.12	Early leavers from education and training	%	destimulant
X7.13	Young people neither in employment nor in education and training (NEET)	%	destimulant
X7.14	Employment rate	%	stimulant
Goal 12 – Responsible consumption and production			
X8.1	Average CO2 emissions from new passenger cars	grams per kilometer	destimulant
X8.2	Circular material use rate	%	stimulant
X8.3	Energy productivity	PPS per kilogram of oil equivalent	stimulant
X8.4	Generation of hazardous and non-hazardous wastes	kilograms per capita	destimulant
X8.5	Gross value added in environmental goods and services sector	% of GDP	stimulant
X8.6	Raw material consumption (RMC)	tonnes per capita	destimulant
X8.7	Consumption footprint – single weighted score	per inhabitant	destimulant