ADOPTION OF DIGITAL TECHNOLOGIES AND REDUCTION OF THE DIGITAL DIVIDE AMONG VULNERABLE GROUPS IN THE EUROPEAN UNION

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ARTICLE INFO

Original Article

Received: *05 May 2025*

Accepted: *28 August 2025*

doi:10.59267/ekoPolj2503927K

UDC 004.6/.9:316.35.024.4 (4-672EU)

Keywords:

Digital economy, Digital divide, DIDIX and IDA Index, Vulnerable groups, European Union countries (27).

***JEL**: O33, O11, C43, O52*

ABSTRACT

In the endogenous theory of economic growth, technological progress is viewed as a crucial factor in the economic development of countries. The advancement of digital technologies and ICT innovations underpins sustainable economic growth over the long term. However, the rapid digital development of the population has not been distributed evenly across all social cohorts. The digital divide stems from insufficient adoption of technology by vulnerable groups. The paper assesses internet use, access to digital devices, and digital skill acquisition among vulnerable groups. The methodological approach includes the computation of the Digital Development Index ("IDA Index") and the Digital Divide Index ("DIDIX Index"). The results indicate substantial growth in digital technology adoption and a reduction of the digital divide among vulnerable groups in EU (27) countries. The research demonstrates the emergence of the second-level digital divide, marked by broad access to digital technologies and devices, alongside persistent gaps in the digital competencies required for their effective utilization.

Introduction

The initial theoretical and methodological research on the adoption of digital technologies and the measurement of the digital divide among different population cohorts gained significant attention in scientific studies at the beginning of the 1990s (Compaine, 2001). The concept of the digital divide implies a basic division into the part of the population

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that has access to digital devices and the internet and the part of the population that does not have such access (Van Dijk, 2017; Soomro et al., 2020). The term "digital divide" acquires a completely different meaning, primarily due to the improvement of the social and economic capital of the population of the observed countries (Raggnedda, 2017). In the scientific literature of the 21st century, the digital divide is recognized as a source of poverty and income inequality among certain population groups (Rogers, 2016). Technological progress is a key factor in economic growth, but it does not result in equal adoption of information and communication technologies (ICT) across all social groups, according to Bartikowski et al. (2018). The digital divide is a result of limited access to the internet and modern digital devices, along with uneven development of digital skills within the population (Korovkin et al., 2023). This divide is often linked to social and economic poverty in society (Lin et al., 2017).

At the beginning of the new millennium, three types of digital divide were presented. Norris and Inglehart (2013) define the global digital divide, which implies a different level of adoption of digital technology between different countries. The digital divide refers to the difference in the availability of broadband internet for the adoption of ICT technology by population cohorts (Mitrović, 2015). The third division is the democratic digital division, which involves monitoring the decisions of government administration and institutions through official websites, while promoting democracy via digital communication with citizens' requests. According to Quan-Haase et al., (2018), there are four distinct forms of the digital divide. The first type of digital divide refers to the availability of the internet and modern digital devices. The second type involves developing the population's digital skills for adopting ICT. The third type of digital divide indicates the economic benefits of using digital technologies, i.e. the intensity of the implementation of buying and selling activities. The fourth type of digital divide relates to the population's use of social media and social networks.

A review of scientific research outlines the evolution of the term "digital divide" from the first and second level to the stage of the third level (Aissaoui, 2022):

1. *First-level digital divide* – this refers to the basic access to the internet and the availability of modern digital devices.
2. *Second-level digital divide* – this encompasses not only access to the internet and digital devices but also the development of skills necessary for effectively using information and communication technology.
3. *Third-level digital divide* – this goes further by including access to the internet, digital devices, and digital skills, along with individuals' ability to evaluate and select online content, considering the benefits of utilizing digital technologies.

The first economic growth models acknowledging technological progress as a key factor for advancing economic development emerged in the second half of the 20th century, which is referred to as "endogenous growth theory." There is a disparity in the population's ability to adopt ICT, leading to the digital divide. During the initial phase

of adopting new digital technologies, the population was divided into two groups: those who had access to the internet and digital devices and those who did not (Yu et al., 2017). However, in the early years of the new millennium, the definition of the digital divide is being broadened by emphasizing the skills necessary for using digital technologies (Van Dijk, 2006). The second level of the digital divide refers to the quality of human capital necessary for implementing ICT. This division implies differences among individuals based on personal characteristics and their motivation to enhance their skills for adopting digital technologies (Shakina et al., 2021). In recent years, the digital divide at the tertiary level has been addressed. It encompasses improvements in business operations as well as the advantages individuals gain from access to information and the ability to critically evaluate online content (Van Deursen and Van Dijk, 2019). A tertiary level of the digital divide is taking place during the "Covid-19" pandemic (Ionescu et al., 2021), with a significant reduction in the digital divide within population cohorts (Aissaoui, 2022; Kotarac, 2024).

In the 21st century, research has been conducted to identify key factors contributing to the digital divide among countries' populations (Mitrović, 2020). Understanding these factors is essential for recognizing the root causes of the digital divide (Scheerder et al., 2017). The following two groups of digital divide determinants are noteworthy:

1. *Sociodemographic factors*
2. *Socioeconomic factors*

Sociodemographic determinants include age structure, income level, educational structure, degree of urbanization, and ethnicity of the population (Hidalgo et al., 2020). On the other hand, socioeconomic determinants represent digital skills and capacities of individuals, motivation to adopt digital technologies, agility in performing work operations through digital devices, and cultural and personal characteristics of individuals (Venkatesh et al., 2014; Mihajlović, & Todorov, 2024). The precise definition of the drivers of the digital divide within the population of the countries was carried out through the determination of sociodemographic and socioeconomic factors (Lythreatis et al., 2022). This research combines various determinants of the digital divide, which relate to the division of society based on the age structure, level of education, gender structure and employment status of population groups.

Based on the results of various scientific research studies, the following hypothesis will be defined and tested:

Ho: The process of advancing technical and technological progress in countries through the development and implementation of ICT achievements is helping to reduce the digital divide among vulnerable groups within the populations of European Union member states (27).

Materials and methods

The methodological framework for assessing the adoption of information and communication technologies and identifying the digital divide among vulnerable groups within the overall population will be developed using a composite index referred to as the "DIDIX Index."The digital divide index is calculated as the ratio between the indicator of adoption of information and communication technologies by a vulnerable group and the value of that indicator for the total population. The digital divide index is formed from indicators for four population cohorts, which are classified according to sociodemographic characteristics based on three sub-indices of digital technology development of a country or group of countries (Hüsing & Selhofer, 2004).

For the calculation of the digital divide composite index, the three sub-indices were used as indicators for the adoption of digital technology by the entire population:

1. Individuals – Frequency of internet use.

2. Internet purchases by individuals.

3. Individuals who have basic or above-basic overall digital skills.

The measurement of the value of three sub-indices to form a composite index of the digital divide is conducted for four vulnerable groups:

1. Individuals, 55 to 74 years old.

2. Females, 16 to 74 years old.

3. Individuals with no or low primary education.

4. Unemployed.

The data for calculating the digital divide index is sourced from the Eurostat database (2015-2023) (category – Science, Technology, and Digital Society). Based on these data, three different sub-indices are calculated for all four vulnerable groups. The sample frame of this research consists of the European Union member states, including the latest accessions in 2003, 2007, and 2013. The study covers the period from 2015 to 2023 while avoiding missing data and structural breaks in the time series before the observed period. The calculation of the "DIDIX Index" is carried out through the value of indicators for the adoption of digital technologies by vulnerable groups to analyze the digital divide within the population of the EU countries.

The calculation of the digital divide index is ensured by defining a predetermined combination of weight values. Logic suggests that each sub-index used in the construction of the composite index should be assigned equal weights. However, a review of the scientific literature confirms that the weights were determined endogenously, i.e., through performance analysis and the harmonization of indicators across countries (Hüsing et al., 2004; Stojković & Kocić, 2024). Namely, the weights for various sub-indices are determined using linear programming methods. Therefore, the values of the

composite indices of the digital divide by country are maximized, without any other combination of weights for the sub-indices that would provide a higher value of the composite index of the digital divide (Vehovar et al., 2006).

The analysis of the digital divide among countries involves the calculation of two key indicators: the ICT Development Index (IDI) and the Digital Divide Index (DIDIX). The sampling frame was created using countries in Europe that represent both ends of the digital development spectrum, including those that are least and most digitally advanced.

The IDI index value is calculated using the following formula:

$$\text{IDI Index} = \frac{1}{n}\sum_{i=1}^{n} f_i \quad (1)$$

$$f_i = 100 * \sum_{j=1}^{m} W_j * \frac{S_{ij}}{S_j} \quad (2)$$

, where the symbol (f_i) refers to the value of individual indices or sub-indices for each of the three categories. For the composite index of ICT technology development of countries, the values of a series of sub-indexes $(j = 1,2,3 \dots 9,10,11)$ were used, for each of the three categories (f_i) $(i = 1, 2, 3)$, W_j indicates the value of the indicator (j) $(j = 1,2,3;\ Sw = 1)$, symbol S_{ij} denotes the value of the indicator (j) within each of the categories $(i)(i = 1, 2, 3)$, the label S_j implies the value of the indicator (j) for all three mentioned categories collectively (ITU Database, 2015-2023).

Results and Discussions

The analysis of the adoption and implementation of ICT is carried out through an insight into the value of digital development indicators, along with the calculation of the digital gap of vulnerable groups within the entire population of countries. Table 2 presents the values of the composite digital divide index ("DIDIX"), which measures the adoption and application of digital technologies by vulnerable groups concerning the entire population of the European Union countries. Based on the change in the value of the digital divide index, the technological development of the observed group of countries will be analyzed in different time units, with a conclusion about the reduction or increase of the digital gap between vulnerable groups within the population of the EU countries (27).

Table 1. Calculation of the digital divide index ("DIDIX"), based on four vulnerable groups within the entire population of EU countries (27)

2015	1 (*0.5)		2 (*0.25)		3 (*0.25)		Didix Index
EU (27)	Frequency of internet use by individuals		Internet purchases by individuals		Digital skills of individuals		
All Indiv.	75%	100%	62%	100%	54%	100%	SB1 + SB2 +SB3+SB4
G_1	50%	66.6	50%	80.6	29%	53.7	Sub-Index 1

G_2	72%	96.0	61%	98.3	51%	94.4	Sub-Index 2
G_3	53%	70.0	45%	72.5	31%	54.4	Sub-Index 3
G_4	71%	94.6	47%	75.8	45%	83.3	Sub-Index 4
Sub-index	40.90		20.45		17.86		**79.2**
2017	1 (*0.5)		2 (*0.25)		3 (*0.25)		Didix Index
EU (27)	Frequency of internet use by individuals		Internet purchases by individuals		Digital skills of individuals		
All Indiv.	79%	100%	65%	100%	55%	100%	SB1 + SB2 +SB3+SB4
G_1	56%	70.8	51%	78.4	31%	56.3	Sub-Index 1
G_2	78%	98.7	63%	96.9	53%	96.3	Sub-Index 2
G_3	75%	75.9	46%	70.7	31%	56.2	Sub-Index 3
G_4	94%	94.9	50%	76.9	44%	80.0	Sub-Index 4
Sub-index	42.53		20.18		18.05		**80.8**
2019	1 (*0.5)		2 (*0.25)		3 (*0.25)		Didix Index
EU (27)	Frequency of internet use by individuals		Internet purchases by individuals		Digital skills of individuals		
All Indiv.	84%	100%	68%	100%	56%	100%	SB1 + SB2 +SB3+SB4
G_1	65%	77.3	53%	77.9	33%	58.9	Sub-Index 1
G_2	83%	98.8	68%	100	54%	96.4	Sub-Index 2
G_3	68%	80.9	50%	73.5	32%	57.1	Sub-Index 3
G_4	79%	94.0	56%	82.3	44%	78.5	Sub-Index 4
Sub-index	43.87		20.85		18.18		**82.9**
2021	1 (*0.5)		2 (*0.25)		3 (*0.25)		Didix Index
EU (27)	Frequency of internet use by individuals		Internet purchases by individuals		Digital skills of individuals		
All Indiv.	87%	100%	74%	100%	54%	100%	SB1 + SB2 +SB3+SB4
G_1	72%	82.7	60%	81.0	35%	64.8	Sub-Index 1
G_2	87%	100	74%	100	52%	96.0	Sub-Index 2
G_3	73%	83.0	56%	75.6	32%	61.5	Sub-Index 3
G_4	86%	98.0	65%	87.0	49%	94.0	Sub-Index 4
Sub-index	45.46		21.47		19.76		**86.6**
2023	1 (*0.5)		2 (*0.25)		3 (*0.25)		Didix Index
EU (27)	Frequency of internet use by individuals		Internet purchases by individuals		Digital skills of individuals		
All Indiv.	90%	100%	75%	100%	56%	100%	SB1 + SB2 +SB3+SB4

G_1	82%	91.1	60%	80.0	37%	66.0	Sub-Index 1
G_2	90%	100	75%	100	54%	96.4	Sub-Index 2
G_3	79%	87.7	57%	76.0	34%	60.7	Sub-Index 3
G_4	98.8%	98.8	64%	85.3	48%	85.7	Sub-Index 4
Sub-index	47.22		21.33		19.30		**87.8**

Source: Author's calculation, based on data from the Eurostat database (2015-2023)

The results in Table 1 indicate the share in which the observed vulnerable groups have access to the internet and modern digital devices, information and purchasing activities, as well as possessing digital skills.

The first vulnerable group is made up of the older population, in the age range from 55 to 74. Due to difficulties in acquiring digital skills and aversion to modern digital devices (Matthews et al., 2019), the older population uses the internet significantly less than other population groups (Gallistl et al., 2021), with insufficient information and purchases through available web platforms (Olphert & Damodaran, 2013). The absence of digital skills and the limitation of physical mobility lead to a decrease in social interactions of the older population (Hill et al., 2015). During 2015, the first vulnerable group used the internet network 25% less than the average usage of the internet across the entire population, which was calculated based on the average of the indicator values of the EU countries (27). During the same period, older members of the population received information about products and services available online and made purchases on e-commerce platforms at a rate 12% lower than the average value of the population of EU countries (27). The lag in the digital skills sub-index was evident. In 2015, the first vulnerable group demonstrated digital skills that were 25% lower than the average for the population of the EU (27) countries. However, by 2023, this group saw a 32% increase in internet usage compared to 2015, reducing their lag to only 8% regarding indicators for the entire EU (27) population. Additionally, the older segment of the population increased their online information gathering and purchases through electronic platforms by 10% from 2015 to 2023. This group also experienced an 8% increase in digital skills, which significantly contributes to the adoption of digital technologies.

The formation of the second vulnerable group was based on an analysis of digital development within the gender structure of the population. The research found that women's use of the internet and their development of digital skills related to adopting ICT are significantly lower compared to that of men (Adkins & Sandy, 2020). In rural regions of various countries, the gender digital divide is more pronounced, making women a particularly vulnerable population (Cortelyou-Ward et al., 2020). Another vulnerable group consists of women aged 17 to 74 (Eurostat Database, 2015-2023). In 2015, this age group of women used the internet, consuming content through websites and social networks, at a rate that was only 3% lower than the average for the entire population of the EU (27) countries. In the same period, information about products

and services and performance of buying and selling activities via e-commerce platforms by women lagged by a negligible 1% compared to the average values for the entire population of the EU (27) countries. In 2015, the development of digital skills for the use of ICT by this vulnerable group lagged by 3% compared to the average digital skills of the entire population of the EU (27) countries. During 2023, internet use by women aged 17 to 74 amounted to 90%, which is equal to the average value of the indicator for the entire population of the EU (27) countries. In the same year, the information-seeking and purchasing activities of this vulnerable group on e-commerce platforms aligned with the average values for the overall population of the EU (27) countries. However, there was a notable exception in digital skills development, where women aged 17 to 74 were 2% behind the average level of digital skills in the EU (27) countries.

The third vulnerable group is formed based on the educational structure of the population (Kim et al., 2021). The quality of human capital and the economic standard of a country are significantly correlated with the educational system of a country (Winters, 2011; Lythreatis et al., 2022). Adoption of ICT is insufficient among a part of the population with or without lower primary education, which has caused the formation of a third vulnerable group (Helsper & Reisdorf, 2017). Therefore, the third vulnerable group in this research involves the part of the population with or without primary education (Eurostat Database, 2015-2023). In 2015, the population with or without primary education used the Internet 22% less compared to the average values of the internet use of the population of the EU (27) countries. Information and purchasing activities through e-commerce platforms are 17% lower than the average values measured at the level of the entire population of the EU (27) countries. The development of digital skills for the adoption of ICT by this vulnerable group was 23% lower than the average indicator of the total population of the EU (27) countries. Internet use and digital devices by the less educated part of the population increased by 16% in 2023 compared to 2015, representing a lag of 11% compared to the indicators for the entire EU population in 27 countries. During 2023, information and purchasing activities on e-commerce platforms of this vulnerable group increased by 12% compared to 2015, which implies a lag of 18% compared to the average indicators of the EU population. The possession of digital skills related to the application of ICT technologies among the less educated population has seen only a modest increase of 3% since 2015. This growth still leaves a 22% gap when compared to the digital skills levels of the population in the EU (27) countries.

The fourth vulnerable group is linked to per capita income, specifically concerning the low standard of living among the population of these countries. This group is primarily composed of individuals from the unemployed segment of the population. The increased rate of unemployment and low income per capita lead to limitations in the availability of the internet and modern digital devices, with the absence of financial resources for the education of individuals (Ueno et al., 2023). The population that faced low socioeconomic status and standard of living has less ability to adopt and implement digital technologies (Helsper & Reisdorf, 2017). Therefore, the fourth vulnerable group consists of the unemployed part of the population of the EU (27) countries. In 2015, the

unemployed population used the internet and consumed the content of websites by 4% less compared to the average values of internet use of the entire population of the EU (27) countries. Information about products and services and purchasing activities via e-commerce platforms was 15% less intense than the number of users of e-commerce platforms in the total population of the EU (27) countries. During 2015, the digital skills of the unemployed population were 9% less developed compared to the average development of skills for using digital devices of the entire population of the EU (27) countries. In 2023, the use of the internet and consumption of online content increased by 27.8% compared to the value measured in 2015. Information about products and services, along with purchasing activities through e-commerce platforms, reached a growth of 17% in 2023 compared to 2015, which also implies a lag of 11% compared to the volume of e-commerce users of the total population of the EU (27) countries. During 2023, the development of digital skills for using digital devices and the adoption of information technologies increased by 3% compared to 2015, with a lag of 8% compared to the measured development of skills of the entire population of the EU countries (27).

Table 2. Values of digital development indicators calculated for the entire population of the 27 countries in the European Union

Countries of EU (27)	Adoption of digital technologies and ICT innovations at the level of total population		
(K_1)-(K_3)	Sub-Index (K_1)	Sub-Index (K_2)	Sub-Index (K_3)
Time Period	Frequency of internet use by individuals	Internet purchases by individuals	Digital skills of individuals
2015-2017	+4%	+13%	+1%
2017-2019	+5%	+3%	+1%
2019-2021	+3%	+6%	-2%
2021-2023	+3%	+1%	+2%
2015-2023	+15%	+13%	+2%

Source: Author's calculation.

The monitoring of changes in the sub-indices that make up the composite index of the digital divide, known as "DIDIX," measures the adoption of ICT among vulnerable groups and the overall population of the 27 EU countries.

Between 2015 and 2023, the frequency of internet use among individuals increased by 15%. During the same period, there was also a 13% rise in the value of internet purchases made by individuals. In contrast, the indicator measuring individuals' digital skills showed only a minimal increase of 2%. Additionally, there was a 13% growth in the value of electronic purchases made by individuals during this time frame. Then, an increase of 2% was measured in the value of the indicator of digital skills. The research results indicate that the growth of digital development is accompanied by improved ICT infrastructure, greater availability of digital devices, and the quality of broadband internet. During the observed period, there was a notable increase in the number of internet users and the use of e-commerce platforms for purchasing activities through digital devices. Human capital has remained relatively stable over time, serving as both

a key factor for technological progress and a prerequisite for adopting ICT innovations. However, it was found that the development of digital skills necessary for implementing these technological advancements is still insufficient among the population of the EU (27) countries.

The calculated values of the digital divide index represent the ratio between the indicators of the acceptance of digital technologies by vulnerable groups and the values of the indicators of the entire population of the observed countries. The calculated value of the DIDIX index is approximately 0, indicating that the adoption of digital technologies among vulnerable groups is extremely low. This reflects a significant disparity in digital development compared to the overall population.

The calculated value of the digital divide index, which is approximately equal to the number 100, indicates that the implementation of digital technologies by vulnerable groups is equivalent to the development and implementation of digital technologies of the average value of the entire population (Vehovar et al., 2006). Namely, an increase in the value of the digital divide index indicates a reduction in the digital gap between vulnerable groups and the entire population of a country or group of countries.

The countries aim to develop and implement ICT while reducing the digital divide between different cohorts within the total population. In 2015, the value of the "DIDIX index" was 79.2 units. Therefore, the four vulnerable groups adopted digital technologies at less than 4/5 of the average implementation by the total population. In 2017, the "DIDIX index" was valued at 80.8 units, indicating that the adoption of digital technologies by vulnerable groups was approximately 4/5 compared to the average of the entire population. Improvements in the ICT infrastructure and increased internet use, the availability of digital devices, and the quality of human capital ensure the reduction of the digital divide of the overall population. During 2019, the value of the "DIDIX index" was 82.9 units. Hence, the adoption of digital technologies by vulnerable groups was higher than 4/5 of the average adoption of digital technologies by the total population. The trend continued during the Covid-19 pandemic when the digital divide index was 86.6 (2021) and 87.8 (2023), which is above 4/5 of the average use of ICT by the total population of EU (27) countries.

The analysis of the digital divide among countries involves the calculation of two key indicators: the ICT Development Index (IDI) and the Digital Divide Index (DIDIX).

Table 3. Calculation of digital development and digital divide of vulnerable groups within the most and least digitally developed European countries

Countries	IDI Index		Index Value	DIDIX Index		Index Value
Time frame	2015	2023	(2015-2023)	2015	2023	(2015-2023)
Sweden	86.7	93.9	%ΔIDI=7.2%	89.51	95.56	%ΔDIDIX=6.05
Denmark	88.8	96.9	%ΔIDI=8.1%	95.55	96.64	%ΔDIDIX=1.09
Germany	82.2	87.3	%ΔIDI=5.1%	86.70	88.21	%ΔDIDIX=1.51
Luxembourg	85.9	92.1	%ΔIDI=6.2%	91.36	89.10	%ΔDIDIX=2.26
France	81.2	89.4	%ΔIDI=8.2%	85.20	89.85	%ΔDIDIX=4.65

Countries	IDI Index		Index Value	DIDIX Index		Index Value
Latvia	71.6	93.8	%ΔIDI=22.2%	75.92	86.09	%ΔDIDIX=10.17
Serbia	64.5	85.1	%ΔIDI=20.6%	68.73	82.53	%ΔDIDIX=13.80
Albania	47.3	84.7	%ΔIDI=37.4%	68.02	81.53	%ΔDIDIX=13.51
Montenegro	59.0	87.9	%ΔIDI=28.9%	60.87	80.12	%ΔDIDIX=19.25
Turkey	55.8	85.8	%ΔIDI=30%	69.53	79.73	%ΔDIDIX=10.20
Bosnia and Her.	52.8	78.6	%ΔIDI=25.8%	72.59	74.12	%ΔDIDIX=1.53
North Maced.	60.7	82.0	%ΔIDI=21.3%	68.61	79.66	%ΔDIDIX=11.05

Source: Author's calculation, based on data from the Eurostat database (2015-2023)

Based on the results from Table 3, European Union member states achieved a digital development growth of 9.5% from 2015 to 2023. During the same period, the countries that are candidates for joining the European Union saw a substantial increase of 27.33% in their digital development. According to the digital divide index, the gap of vulnerable groups has been reduced to a level of 90.92, which is above 4/5 of the overall digital development of the entire population. Meanwhile, candidate countries have reduced the digital divide to the level of 79.62, which is below 4/5 of the total population.

The conclusion is provided through a comparison of the calculated values of the digital divide of member countries and candidates for joining the European Union. During 2023, the digital divide in the EU (27) countries was 87.8. Namely, the group of candidate countries for EU membership, i.e., digitally less developed countries, had an 8.2% higher digital gap of vulnerable groups in the total population, compared to the average digital divide of EU (27) countries. On the other hand, the group of EU (27) member states, i.e., highly digitally developed countries, achieved a 3.1% lower level of digital divide of vulnerable groups within the total population, compared to the average digital gap of EU (27) countries. The development of ICT technologies in the candidate countries for EU membership is increasing 2.9 times faster than in the EU member states. European Union member states reduced the digital divide by 11.3% more than candidate countries for EU membership.

Conclusion

The digital divide among the population is a consequence of the rapid development of information and communication technology. This divide highlights the uneven adoption of digital technologies across different groups. Factors contributing to the unequal use of these technologies include an underdeveloped ICT infrastructure and limited availability of digital devices in various regions of the observed countries. Key barriers preventing equal access to digital technologies for all social groups include a lack of digital skills, inadequate education levels, insufficient training and skill development for employees, and lower per capita income among vulnerable populations.

The values of three sub-indices within the composite index of the digital divide were calculated to analyze the digital gap of four vulnerable groups within the population of EU countries. The greatest growth in the use of the internet and consumption of content on websites was measured within the first vulnerable group (Individuals, 55-74). The highest sub-index values were measured in the second and fourth vulnerable groups (Females, 17-74 & Unemployed) in terms of purchasing activities via e-commerce platforms, with information about products and services. Finally, the greatest improvement in the development of digital skills was measured within the first vulnerable group (Individuals, 55-74). The calculation of the DIDIX index confirms the direct negative correlation between the sudden influx of ICT and the reduction of the digital divide within the population of the EU countries.

The most digitally developed EU countries had an almost three times lower growth in ICT technologies, but a double-digit reduction in the digital gap, compared to less digitally developed countries that are candidates for membership in the European Union. Namely, the lack of infrastructure for the implementation of ICT, insufficiently developed e-commerce platforms, and digital skills caused the uneven adoption of ICT technologies in different population cohorts. The first two indicators refer to the use of the internet and the consumption of content on websites, with information about products and services, and the realization of purchasing activities, a double-digit percentage increase was achieved in all four vulnerable population groups in the European Union countries.

The increase in digital skills necessary for implementing digital technologies among the four vulnerable groups is only a single-digit percentage. This research indicates that an effective approach to bridging the digital divide between vulnerable groups and the entire population of the EU (27) countries has not been established. Adopting digital technology successfully requires more than just developing ICT infrastructure and ensuring access to digital devices; it also necessitates enhancing digital skills to effectively utilize technological innovations and ICT solutions.

To reduce the digital divide affecting vulnerable population groups, it is essential to focus on developing human capital and improving the educational system. This includes providing additional training and education for employees and citizens to enhance the overall digital skills of the population.

The recommendation for the creators of national strategies regarding the implementation of information and communication technologies involves raising awareness that overcoming physical barriers to the application of ICT is a necessary but not a single condition for reducing the digital divide within the population. A comprehensive approach implies improving the educational system to develop digital skills and competencies, all to reduce the digital divide and achieve the general social well-being and economic prosperity of countries.

Acknowledgements

The result of the research study is within the frameworks of the scientific-research work implementation and funding in the year 2025 made between the Belgrade Faculty of Agriculture and the Ministry of Education, Science and Technological Development of the Republic of Serbia, Agreement Registration Number: 451-03-137/2025-03/200116

Conflict of interests

The authors declare no conflict of interest.

References

1. Adkins, D., & Sandy, H. M. (2020). Information behaviour and ICT use of Latina immigrants to the US Midwest. *Information Processing & Management*, *57*(3), 102072.
2. Aissaoui, N. (2022). The digital divide: a literature review and some directions for future research in light of COVID-19. *Global Knowledge, Memory and Communication*, *71*(8/9), 686-708.
3. Bartikowski, B., Laroche, M., Jamal, A., & Yang, Z. (2018). The type-of-internet-access digital divide and the well-being of ethnic minority and majority consumers: A multi-country investigation. *Journal of Business Research*, *82*, 373-380.
4. Compaine, B. M. (2001). Re-examining the digital divide. *Communications policy in transition: The Internet and beyond*, 321-350.
5. Cortelyou-Ward, K., Atkins, D. N., Noblin, A., Rotarius, T., White, P., & Carey, C. (2020). Navigating the digital divide: barriers to telehealth in rural areas. *Journal of health care for the poor and underserved*, *31*(4), 1546-1556.
6. Eurostat Database (2015-2023). Link: https://ec.europa.eu/eurostat/web/digital-economy-and-society/database
7. Gallistl, V., Rohner, R., Hengl, L., & Kolland, F. (2021). Doing digital exclusion–technology practices of older internet non-users. *Journal of Aging Studies*, *59*, 100973.
8. Helsper, E. J., & Reisdorf, B. C. (2017). The emergence of a "digital underclass" in Great Britain and Sweden: Changing reasons for digital exclusion. *New media & society*, *19*(8), 1253-1270.
9. Hidalgo, A., Gabaly, S., Morales-Alonso, G., & Urueña, A. (2020). The digital divide in light of sustainable development: An approach through advanced machine learning techniques. *Technological forecasting and social change*, *150*, 119754.
10. Hill, R., Betts, L. R., & Gardner, S. E. (2015). Older adults' experiences and perceptions of digital technology:(Dis) empowerment, wellbeing, and inclusion. *Computers in Human Behavior*, *48*, 415-423.

11. Hüsing, T., & Selhofer, H. (2004). DIDIX: A digital divide index for measuring inequality in IT diffusion. *It & society*, *1*(7), 21-38.
12. Ionescu, C., Iordache, M., & Țițan, E. (2021). The impact of digitization on economy in the context of the Coronavirus pandemic. In *SHS Web of Conferences* (Vol. 92, p. 01018). EDP Sciences.
13. Kim, H. J., Yi, P., & Hong, J. I. (2021). Are schools digitally inclusive for all? Profiles of school digital inclusion using PISA 2018. *Computers & Education*, *170*, 104226.
14. Korovkin, V., Park, A., & Kaganer, E. (2023). Towards conceptualization and quantification of the digital divide. *Information, Communication & Society*, *26*(11), 2268-2303.
15. Kotarac, Đ. (2024). The impact of the Covid-19 pandemic on reducing the digital divide of the population of Serbia. *Faculty of Economics Prilep*, 327. Doi: 10.20544/EBSiDE.02.01.24.p30
16. Lin, C. H. A., Lin, H. S., & Hsu, C. P. (2017). Digital divide and income inequality: a spatial analysis. *Review of Economics and Finance*, *8*, 31-43.
17. Lythreatis, S., Singh, S. K., & El-Kassar, A. N. (2022). The digital divide: A review and future research agenda. *Technological Forecasting and Social Change*, *175*, 121359.
18. Matthews, K., Nazroo, J., & Marshall, A. (2019). Digital inclusion in later life: cohort changes in internet use over a ten-year period in England. *Ageing & Society*, *39*(9), 1914-1932.
19. Mihajlović, M., & Todorov, J. (2024). Analiza uticaja nedostatka resursa i satisfakcija stanovništva. *Održivi razvoj*, *6*(1), 47-62. https://doi.org/10.5937/OdrRaz2401047M
20. Mitrović, Đ. (2015). Broadband adoption, digital divide, and the global economic competitiveness of Western Balkan countries. *Economic Annals*, *60*(207), 95-115.
21. Mitrović, Đ. (2020). Measuring the efficiency of digital convergence. *Economics Letters*, *188*, 108982.
22. Norris, P., & Inglehart, R. (2013). Digital divide. In *Handbook on the digital creative economy* (pp. 90-102). Edward Elgar Publishing.
23. Olphert, W., & Damodaran, L. (2013). Older people and digital disengagement: a fourth digital divide?. *Gerontology*, *59*(6), 564-570.
24. Quan-Haase, A., Williams, C., Kicevski, M., Elueze, I., & Wellman, B. (2018). Dividing the grey divide: Deconstructing myths about older adults' online activities, skills, and attitudes. *American Behavioral Scientist*, *62*(9), 1207-1228.
25. Ragnedda, M. (2017). *The third digital divide: A Weberian approach to digital inequalities*. Routledge.

26. Rogers, S. E. (2016). Bridging the 21st century digital divide. *TechTrends*, *60*(3), 197-199.

27. Scheerder, A., Van Deursen, A., & Van Dijk, J. (2017). Determinants of Internet skills, uses and outcomes. A systematic review of the second-and third-level digital divide. *Telematics and informatics*, *34*(8), 1607-1624.

28. Shakina, E., Parshakov, P., & Alsufiev, A. (2021). Rethinking the corporate digital divide: The complementarity of technologies and the demand for digital skills. *Technological Forecasting and Social Change*, *162*, 120405.

29. Soomro, K. A., Kale, U., Curtis, R., Akcaoglu, M., & Bernstein, M. (2020). Digital divide among higher education faculty. *International Journal of Educational Technology in Higher Education*, *17*, 1-16.

30. Stojković, A., & Kocić, S. (2024). Analysis of stress disorders and public speaking. Finansijski savetnik - časopis za pravo i finansije, 1(29).27-38.

31. Ueno, A., Dennis, C., & Dafoulas, G. A. (2023). Digital exclusion and relative digital deprivation: Exploring factors and moderators of internet non-use in the UK. *Technological Forecasting and Social Change*, *197*, 122935.

32. Van Deursen, A. J., & Van Dijk, J. A. (2019). The first-level digital divide shifts from inequalities in physical access to inequalities in material access. *New media & society*, *21*(2), 354-375.

33. Van Dijk, J. A. (2006). Digital divide research, achievements and shortcomings. *Poetics*, *34*(4-5), 221-235.

34. Van Dijk, J. A. G. M. (2017). Digital divide: Impact of access. *The international encyclopedia of media effects*, *1*, 1-11.

35. Vehovar, V., Sicherl, P., Hüsing, T., & Dolnicar, V. (2006). Methodological challenges of digital divide measurements. *The information society*, *22*(5), 279-290.

36. Venkatesh, V., Sykes, T. A., & Venkatraman, S. (2014). Understanding e-Government portal use in rural India: role of demographic and personality characteristics. *Information systems journal*, *24*(3), 249-269.

37. Winters, J. V. (2011). Human capital, higher education institutions, and quality of life. *Regional Science and Urban Economics*, *41*(5), 446-454.

38. World Telecommunication/ICT Indicators Database (2015-2023). Link: https://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx

39. Yu, T. K., Lin, M. L., & Liao, Y. K. (2017). Understanding factors influencing information communication technology adoption behavior: The moderators of information literacy and digital skills. *Computers in human behavior*, *71*, 196-208.