"Digital divide and sustainable development of Ukrainian regions"

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DIGITAL DIVIDE AND SUSTAINABLE DEVELOPMENT OF UKRAINIAN REGIONS

Abstract

Digital inequality of the regions is considered one of the topical issues of sustainable development provision in less developed countries. It can be defined as a gap between the geographical areas regarding the access opportunities to ICT and the Internet use for different activities. The goal of the study is to identify the link between the regional digital divide and the level of economic development in Ukraine and generalize international practices of digitalization promotion in lagging regions. Methodologically, various statistical methods (analytical grouping, variation, and correlation analysis) were used. The most appropriate and available data for assessing the digital divide referred to the State Statistical Service of Ukraine's survey on Internet users in Ukrainian regions. The study revealed an overall shrink in the variation coefficient of the share of Internet users (from 36.4% in 2010 to 10.2% in 2019). However, the variation coefficients for the share of interacting with public authorities, reading online, and e-mailing persons remain significant.

Furthermore, analytical grouping of regions suggested that the level of industrial sector development influenced the penetration of digital technologies into public life vastly, though several unaccounted factors also existed. Finally, the paper examined international practices of managing the digital divide. As a result, recommendations for public policy (e.g., the implementation of training programs for late adults and elderly, improved digital maintenance and digitalization programs for schools, price equalization for digital technologies, equal Internet provision in different regions, and investments in services digitalization) were developed.

Keywords	region, digitalization, industrial technologies, online education, e-governance
JEL Classification	L86, L96, Q01, R11

INTRODUCTION

Today the regional dimension of sustainable socio-economic development has become one of the top research areas. European countries and Ukraine have declared the Sustainable Development Goals for 2030 and begun to shape their policies accordingly. Regional and territorial dimensions of socio-economic development in many European countries and the rest of the world form a contrasting picture of multiple and varying spatial disparities. For example, the development of information technologies accelerated digitalization resulting from the COVID-19 pandemic. Moreover, subversive Industry 4.0 technologies have added digital inequality to the list of mentioned disparities.

The increasing concentration of digital solutions for different processes and routines of human life creates inseparable links between digital inequality and the Sustainable Development Goals for 2030. For example, equal access to education (Goal 4) under quarantine and distance learning cannot be ensured without equal access to digital technologies, Internet, and relevant equipment. Ensuring public access to information, protecting fundamental freedoms and democracy (relat-

ed to Goal 16) lies in the independency of institutions and access to public digital services like e-governance. The same relates to the right to work, when jobs are transformed into remote ones; to health, when communication with a doctor or ordering medicines is digitalized; to combating climate change, which requires raising public awareness. Moreover, the most important is reducing inequality through political and socio-economic inclusion of each citizen, regardless of age, gender, race, ethnicity, religion, income level, or another status. Digital technologies ensure such inclusion, especially in hard-to-reach areas – mountains, islands, etc. Thus, the "non-digitization" of local communities poses a new threat to implementing the SDGs 2030.

The reasons for the uneven digitalization of communities mentioned in various studies are related to the low-income level and other financial constraints; low-quality or expensive connection to electric or communication networks; lack of digital literacy; poor technical support and limited access to high-quality ICT content; poor education, etc. (Stoiciu, 2011).

The decentralization policy in Ukraine has created growing financial capabilities to improve regional infrastructure. However, at the initial stages of the decentralization reform, regional inequalities usually deepen due to the discrepant speed of adaptation to new economic conditions (Deineko & Tsyplitska, 2020). The differences laid earlier in the regional development – structural, technological, social, and geographical – denoted significant inertia of divergence. These were the agrarian or industrial characters of a region that could distinguish the level of its digitalization.

The inequality in regional digitalization is considered a significant determinant of the regional population exclusion from participation in national economic and political processes, which are increasingly becoming digitized. Furthermore, it creates issues with ensuring the uniformity of sustainable development throughout Ukraine and is a threat to democratic values. Thus, these provisions significantly determine the topicality of the study.

1. LITERATURE REVIEW

The global processes such as digitalization, the introduction of Industry 4.0 technologies, pandemic shocks, and the transition to the "new normality" were external factors that adjusted the approaches of sustainable development policies. For example, digitalization has shaped the basis of many UN Sustainable Development Goals – gender equality, quality healthcare and education, industrial innovations, and sustainable development of cities. Moreover, reaching all the Goals calls for ensuring strong information and communication systems (Gillwald, 2018; FAO, 2021).

The digital divide has become a subject of scientific interest at the end of the XX century. According to the OECD (2001) report "Understanding the Digital Divide," it is determined as "the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard both to their opportunities to access information and communication technologies

(ICTs) and to their use of the Internet for a wide variety of activities."

Scientists began to study the processes of the digital divide and public policy in three important contexts:

1) concerning the causes of digital inequality and its connection to the Sustainable Development Goals for 2030;

2) describing the experience of different countries in overcoming digital inequality and reducing the gap;

3) pondering the regional perspective of unequal access to digital technologies, particularly in Ukraine.

A thorough analysis of more than 200 early publications (1999–2010) on the causes of the digital divide was held by Mwin and Kritzinger (2016) and Srinuan and Bohlin (2011). They concluded

that the early research highlighted uneven development of ICT infrastructure, the insufficiency of digital skills, and the geographical location of digital technology suppliers and consumers as the digital divide determinants. On the other hand, age, occupation, gender, cultural values, language, content, and attitude to ICT were recognized as less critical. Publications considering the impact of the latter factors fell to the end of the analyzed period, which revealed higher complexity of the digital divide mechanism.

In a few recent publications, one can see how the focus and angle of research have changed in search of the cause of the digital divide.

The development of the Fourth Industrial Revolution and the accelerated digitalization drew attention to the issue of digital gender inequality that has affected women globally. This challenge has been deeply explored by Kuroda et al. (2019). The problem combines the Sustainable Development Goal 5 "Gender Equality" and Goal 10 "Reduced Inequalities," associated with income disparities. They determined three issues: access to digital technologies, digital skills development, and promotion of women to leadership positions, which related to women's digital inequality. At the same time, it was also noted that the gap in access to digital technologies can be huge even between the regions of the same country. However, the regional level was not considered in detail.

The role of the digital divide in the context of quality education was emphasized during the UN Forum in 2019 (UN, 2019). The speakers pointed out the possibility of reducing digital inequality by training young people in programming and other operations with information and communication technologies. Hidalgo et al. (2020), referring to Goals 10 "Reduced inequalities" and 12 "Responsible production and consumption," consider unequal access to digital technologies in the context of gaining digital skills caused by age, education, and occupation. Neagu et al. (2021) and Shirazi and Hajli (2021) highlight a considerable differentiation in the magnitude of digital skills of youth in rural territories. This creates additional barriers to entering the labor market. At the same time, this differentiation is due to the generally low level of education available to the younger

generation in less economically developed areas. Thonipara et al. (2020) add smaller entrepreneurship opportunities in the rural areas. An assessment of the small and medium-sized firms' websites in Germany has shown that those in urban areas are almost twice as likely to have websites than those located in rural areas. This leads to "vicious cycles" in such areas; thus, it is proposed to introduce mobility-increasing activities for youth to achieve digital inclusion. Substantive education reform, especially in the STEM area, may also be of great benefit. Myeong et al. (2014) show that equal e-governance introduction may help establish better communication between civil society and the government. In addition, it relates to a higher level of education.

UN (2021) has focused on the impacts of COVID-19. For example, accelerating digitalization in terms of the physical remoteness of individuals has deepened inequality. Another significant reason was the energy supply problem (the so-called "energy gap"). In addition, the report calls for environmental friendliness of solutions to overcome digital gaps.

Analyzing the Chinese digital divide in regional dimension, Ding et al. (2022), Song et al. (2019), and Zhang et al. (2018) examined the state of digitalization in Chinese regions measuring the Informatization Level Index and ICT Development Index. Significant disparities (up to 5-6 times) were found between the provinces. Also, a close relationship was noted between the level of economic development, the quality of education, and the extent of digitalization of the country's areas. It is emphasized that there is a need to implement the "Digital China" strategy, develop technological infrastructure, increase public support for innovation as a driver of digitalization, and focus on training programs for talented specialists.

Another set of studies show that intensive digitalization, along with great opportunities for regional development, could pose some risks: reduced employment and uncompetitiveness of human labor compared to robotics, lack of digital skills (Rajnai & Kocsis, 2017); vulnerability of digitalized management and production systems to cyberattacks (KPMG, 2019); possible produc-

tion interruption due to dependence on closely related technologies (Deloitte, 2018); radical business changes (i8 Ventures, 2019), which need to be controlled.

Srinuan and Bohlin (2011) point out that the digital divide is actively discussed at the global and civil dimensions. However, there is a lack of discourse at the level of states, regions, and organizations. They argue that a combined policy based on market mechanisms and state intervention, as well as on the integration of social, political, and cultural aspects, should be implemented.

While income is important, it holds the last place on the impact level list. Nevertheless, the role of income in digital inequality was confirmed by UNCTAD (2006). The newly developed ICT Diffusion Index closely correlates with the countries' income. Also, UNCTAD (2019, 2021) states that less developed countries suffer from inequalities in access to mobile Internet. The rapid penetration of mobile phones and the virtualization of life at the global level have a particularly noticeable effect on those segments of the population that may have devices but still are not able to take advantage of all their capabilities.

Nevertheless, Pagán et al. (2018) and Stoiciu (2011) demonstrate that the lower-income population remains underequipped for quality Internet access, independently of their area of residence. In the UNCTAD (2019) report, the digitalization of the socio-economic space is perceived as a new value in public life. The platformization, e-commercialization, and digitalization of value chains are considered means to create this value. Particular attention should be paid to labor market regulation and social protection, as well as streamlining tax regulation of the digital sphere, strengthening the protection of intellectual property rights, competitive policies, and data policies.

Beynon-Davies and Hill (2007) raised the digital divide issue due to the deficiency of users in a specific territory necessary to form a critical mass of citizens to get digital access and communications channels. This critical mass is an essential basis for regional digital alignment. They created the Digital Divide Index (DDIX). At the example of the United Kingdom, they identified four causes of digital inequality (gender, age, education, and income), differently impacting regional sustainable development. For example, no significant disparities in digital development by gender and income in the Welsh region have been identified.

Chmeruk and Kralich (2018) used Huawei's Global Connectivity Index to analyze digital gaps in Ukraine and their dynamics. They found that urban localities had the most extensive broadband coverage – but their number was several times smaller than the rural ones. The study also noted the lack of statistical data for monitoring digital development in Ukraine compared to the EU as a weak strategy for digital development.

Kolodiziev et al. (2018) revealed significant disparities and divided the regions into four clusters around them. The capital region (Kyiv) (the first cluster) was the most polarized. The second cluster included million-regions – Dnipropetrovsk, Lviv, Odesa, and Kharkiv regions, which, in turn, are marked by a significant level of gross regional product per capita. The less affluent regions were in third and fourth groups. A tight correlation for the regional levels of socio-economic development and the quality of information and communication infrastructure has been observed, as well as deceleration of areal distribution of resources, which weakened the outcomes of intensive (innovative) determinants of economic growth and an increase in extensive ones.

It can be summarized that regional grouping, clustering, and index methods are mainly used to assess the state of the digital divide.

Thus, the analyzed literature allows establishing close links between digital inequality and the Sustainable Development Goals achievement. At the same time, the plurality of the considered aspects and the small number of regional studies for Eastern European countries needs an additional assessment of the state of the digital divide, its dynamics, and possible causes.

The goal of the study is to identify the link between regional digital divide and the level of economic development in Ukraine, as well as the generalization of international practice of promotion of digitalization in lagging regions.

2. DATA AND METHODS

An array of indicators from 2019 have been used to test the hypothesis along with quadratic variation coefficient to determine the differentiation among the regional development (Internet usage and spread of e-governance), as well as gross regional product per capita (GRP per capita), presented in the reports of the State Statistical Service of Ukraine (n.d.). This will test the most common hypothesis about the relationship between income level and the digital gap, as well as determine the dynamics of this relationship.

For the quadratic variation coefficient (V_σ), formula (1) was used:

$$V_\sigma = \frac{\sigma}{\bar{x}} \cdot 100, \qquad (1)$$

where σ – standard deviation; $\bar{x}$ – mean value.

The calculations were provided for 19 indicators of digital development of regions, including dynamics for 2010, 2017–2019, which allows assessing trends in the change of digital inequality. Next, 24 were grouped based on the gross regional product per person. The city of Kyiv (capital) was excluded from this grouping since polarized values distort the results in other regions.

To determine the number of groups, the Sturges' rule was used (2):

$$K = 1 + 3.322 \lg N, \qquad (2)$$

where K – the number of groups; N – the number of regions.

The total number of groups for analytical grouping according to (2) was five. Moreover, four analytical groups were built according to the following grouping features: GRP per capita to identify a possible link between digital inequality and income; share of industrial value added in GRP to assess the impact of the regional economy on the digital capabilities of the region; industrial sector value added per capita, and manufacturing value added per capita to assess the relationship between technological changes in the industrial sector, and in the processing sector in particular, as well as the level of digitalization of the regions.

The industrial sector includes quarrying and mining, manufacturing, as well as energy and water supply and waste management.

One of the critical points was the selection of an indicator that measured the level of digitalization of the region. Considering the availability of official statistics for the regional context, the share of Internet users in the region's total population was chosen as an indicator. However, it should be noted that this indicator is the result of a sample survey conducted among the population of the regions.

Other indicators distributed by groups of regions consisted of the results of the statistical survey sample conducted by the State Statistics Service of Ukraine (n.d.):

- the share of the population using the Internet for study and education, since access to education through digital technologies, especially in pandemic conditions where people's mobility is limited, falls into the SDG 4;

- the share of the population using the Internet services to interact with public authorities, considering SDG 16, which provides access to justice to everyone and creates effective, transparent, responsible, and based on the broad participation institutions.

According to Gillwald (2018), surveys act today as the most reliable data sources on digitalization outcomes, as well as establish the necessary vectors of state information policy more clearly.

The initial data for statistical analysis are provided in Table 1.

The analytical grouping was carried out based on the State Statistical Service of Ukraine data for 2019. Unfortunately, official statistics to assess the impact of COVID-19 are still not available, which somewhat makes the conclusions from this study conditional. However, at the same time, their value is to outline the current retrospective of the digital divide and trends by 2020.

For each group, general variation σ^2 (3) and between-group variation δ_x^2 (4) are calculated:

Table 1. Socio-economic and digital development of Ukrainian regions, 2019

Region	Indicator					including	
	GRP per capita, UAH	Industrial sector value added per capita, UAH	Manufacturing value added per capita, UAH	Share of industrial sector's value added in GRP, %	Internet users, % to regional population	Use of the Internet for study and education, %	Use of the Internet for communication with public authorities, %
Vinnytsia	83,133	14,529.8	11,226.6	20.5	64.4	23.8	1.7
Volyn	73,176	9,298.6	8,281.5	14.6	57.3	21.2	1.5
Dnipropetrovsk	122,303	44,897.1	20,363.9	44.1	77.8	27.4	5
Donetsk	49,385	39,993.9	18,755.2	49.9	76.8	15.2	3.5
Zhytomyr	70,225	11,232.2	7,060.3	18.4	65.4	20.5	2.2
Zakarpattia	48,853	5,667.2	3,916.0	13.1	77.9	22.6	1.3
Zaporizhzhia	91,452	28,910.1	19,594.8	39	71.3	23.3	1.8
Ivano-Frankivsk	63,237	16,173.2	7,011.7	29.3	76.4	30	2.6
Kyiv	123,216	20,557.7	15,742.0	19.2	60.6	23.3	0.0
Kirovohrad	77,788	12,830.9	7,451.7	19	56	18.3	0.5
Luhansk	18,793	8,259.3	4,229.0	18.3	67.4	20.7	4.6
Lviv	85,177	14,957.5	8,607.6	20	70.2	22.5	0.8
Mykolaiv	82,121	14,866.9	9,378.1	20.7	70.5	23.5	2
Odesa	82,879	8,653.8	7,070.6	11.7	76.3	27.5	1.8
Poltava	134,383	55,019.5	16,085.2	47.6	60.8	28.1	0.9
Rivne	58,318	12,094.5	6,318.5	23.7	69.1	18.2	0.3
Sumy	70,550	14,190.3	8,274.5	23.1	71.6	29.9	0.7
Ternopil	54,821	6,273.3	4,814.2	13	61	24.3	3.6
Kharkiv	92,837	22,252.8	9,742.1	28.3	70.4	19.5	1.7
Kherson	59,972	7,572.9	5,316.3	14.6	65.5	25.6	4.2
Khmelnytskyi	65,893	8,751.0	6,018.8	15.1	61.1	20.9	0.8
Cherkasy	86,279	17,280.7	14,281.9	24	66.2	22.7	2
Chernivtsi	46,135	4,481.0	2,500.6	10.9	72.2	31.2	4.7
Chernihiv	78,098	13,653.8	8,265.2	20	62.7	22.1	4.1
Kyiv city	320,897	28,117.1	15,948.7	9.8	81.4	29	4.5

$$\sigma^2 = \frac{\sum_1^n (x_i - \overline{x})^2}{n-1}, \qquad (3)$$

where n – the quantity of observations; x_i – i-th feature value.

$$\delta_x^2 = \frac{\sum_1^k (\overline{x}_i - \overline{x})^2 \cdot m_j}{\sum_1^k m_j}, \qquad (4)$$

where k – number of groups; m_j – number of features in a group j.

Between-group variation shows the result of the influence of the factor underpinning the grouping, and the extent of its impact is shown by the correlation relationship η (5):

$$\eta = \sqrt{\frac{\delta_x^2}{\sigma^2}}, \qquad (5)$$

η-indicator allows checking whether digital inequality is caused by the grouping feature – GRP per capita

or industrial development indicators. The closer this indicator is to 1, the greater the change in the effective feature (indicator of the spread of digital technologies in the region) due to the sign of grouping. This stage is a critical milestone to assess the possible impact of income level on digitalization which is actively discussed in analyzed literature. For example, most European countries demonstrate fewer regional differences in socio-economic development than Ukraine despite internal regional development disproportions. Figure 1 presents an index of regional disparities in European countries and Ukraine, which is the ratio of the GRP per person to 20% of the richest regions and 20% of the poorest regions. It can be observed that, unlike most European countries, the stratification of the Ukrainian regions is higher, at least according to the official statistics: Regional Disparity Index is 3.64, which means the richest regions are more productive than the poorest several times over.
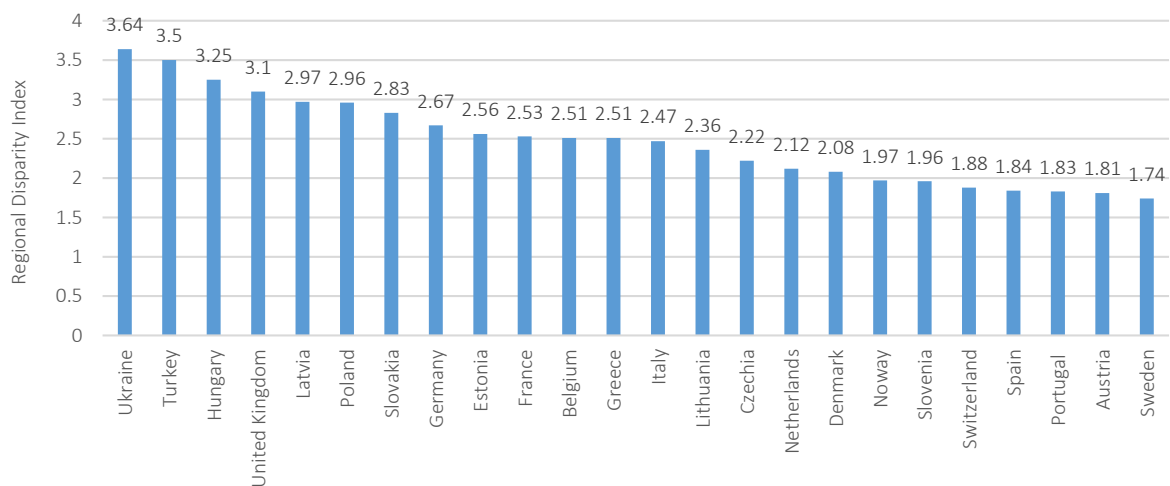
Figure 1. Regional Disparity Index in the European countries in 2018

The statistical analysis allowed identifying trends in digital differentiation between regions and the factors that determine it. Moreover, recommendations for national and regional digital development policy were developed.

3. RESULTS

The concept of the digital divide has been evolving over a long time. However, it has generally been defined as a social problem associated with differences in the amount of information between those who have access to information and communication technologies and are part of the information society and those who do not have such access (Stoiciu, 2011).

Today, there are several digital development indices in various fields, created by Cisco (2020), The Fletcher School at Tufts University (Chakravorti et al., 2020), and Statista (2021a), among others. Cisco (2020) calculates the Global Digital Readiness Index considering such metrics as essential needs, human capital, amount of investments, ease of business startup and the quality of ecosystem, and technological infrastructure. Digital Intelligence Index by The Fletcher School at Tufts University (Chakravorti et al., 2020) demonstrates the progress made by countries in digitalization, building trust and connectivity of billions of people. It considers access to digital technologies and determinants that ensure sustainability and the equality of countries' capabilities in digitalization like

the accountability of institutions, reliability of data, cybersecurity policies, etc. Statista (2021a) offers Digital Competitiveness ranking by country evaluated on the basis of a country's readiness to sustain digital technologies and their implementation at manufacturing companies and public institutions.

Poland and other European countries have lower regional inequality (Deineko et al., 2020) than Ukraine (Table 2).

Poland, Bulgaria, Hungary, Romania, and Estonia were chosen for comparison – either as Ukraine benchmarks itself against them in a lot of socio-economic and regional development issues, or they lead (in the Estonian case) in the digitalization transformation among the transformation economies. In 2015, Estonia was seen as a country with significant territorial development disparities (European Commission, 2015). At the same time, thanks to the EU funding, the country managed to reduce the level of regional disparities. Moreover, thanks to digital technologies, it established effective interstate communications with Finland, which is important for foreign trade and cultural exchange between countries.

It is possible to estimate the digitalization disparities among regions based on the dynamics of variation coefficients for the population using the Internet (Table 3).

In 2010–2019, the spread of the Internet and mobile communications in peripheral territories, as

Table 2. Ukraine in various world digital indices compared to other countries

Index	Countries					
	Ukraine	**Bulgaria**	**Estonia**	**Hungary**	**Poland**	**Romania**
Cisco Global Digital Readiness Index 2019, score	11.47	13.72	17.14	14.13	14.94	13.34
The Fletcher School at Tufts University's Digital Evolution Score, 2020 (*State/Momentum**)	46.03/49.21	57.14/55.07	76.66/48.97	57.75/30.64	63.58/57.29	54.06/45.01
Country-level digital competitiveness rankings worldwide (Statista, 2021a), score	50.07	50.78	75.42	55.23	60.94	51.97

Note: * *State* represents the current state of digitalization; *Momentum* represents the pace of digitalization over time.

Table 3. Coefficients of variation for regional digital disparities in 2010 and 2019

N	Indicator	Variation coefficient, %	
		2010	**2019**
1.	Share of Internet users in regional population	36.4	10.2
Including with the purpose of			
1.1	E-mailing	30.9	31.3
1.2	Interaction with public authorities	77.7	68.3
1.3	Study and education	18.1	17.3
1.4	Reading online/downloading newspapers, magazines	24.5	31.4
1.5	Downloading movies, images, music; watching TV and video	–	16.0
1.6	Playing/downloading video or computer games	–	17.6
1.7	Downloading software	–	53.8
1.8	Phone calls via Internet, Volp	–	23.3
1.9	Communication (hobby)	14.8	14.4
1.10	Banking services	107.8	36.7
1.11	Searching for information about health care	24.1	18.2
1.12	Ordering goods and services	71.0	32.0
1.13	Getting information about other goods and services	43.4	36.0
2.	Number of Internet subscribers	–	167.0
3.	Number of public and local authorities ensuring e-governance possibilities (as of 2020)	–	35.0
4.	GRP per capita	57.7	64.6
5.	Industrial sector value added per capita	75.4	52.8
6.	Share of industrial sector value added in GRP	44.7	49.6

Note: "–" no data.

inevitable progress of public informatization in the context of globalization, has ensured a reduction in digital inequality. However, at the same time, some of its indicators remained alarming. In particular, the coefficient of variation exceeds the value of 25% (as a high indicator variability) in indicators 1.1, 1.2, 1.4, 1.7, 1.10, 1.12, 1.13, and 2-6. As for the indicator of industrial development in the region (as a driver of innovative and digital changes of the Industry 4.0), the disparities of the industrial sector in GRP have increased (from 44.7 to 49.6%), while value added decreased (from 75.4 to 52.8%). This ratio may be explained by the general trend of deindustrialization observed in Ukraine in recent years.

The conducted analytical grouping, based on several indicators of socio-economic development, made it possible to determine whether such stratification is the cause or consequence of digital inequality among the regions during the acceleration of social and economic digitalization.

The results of an analytical grouping of digital indicators of regions based on grouping features and correlation relationship calculation are presented in Tables 4-7.

Manufacturing can be singled out from the industrial sector as an innovation hub and the leading

Table 4. Analytical grouping by GDP per capita

Source: Authors' calculations based on the State Statistical Service of Ukraine (n.d.).

Groups by GRP per capita, UAH	Regions	A*	B*	C*
18,793-41,911	Luhansk			
41,911-65,029	Chernivtsi, Zakarpattia, Donetsk, Ternopil, Rivne, Kherson, Ivano-Frankivsk			
65,029-88,147	Khmelnytskyi, Zhytomyr, Sumy, Volyn, Kirovohrad, Chernihiv, Mykolaiv, Odesa, Vinnytsia, Lviv, Cherkasy	X	X	X
88,147-111,265	Zaporizhzhia, Kharkiv			
111,265-134,383	Dnipropetrovsk, Kyiv, Poltava			
Between-group variation δ_x^2		7.03	0.55	1.85
General variation σ^2	X	48.5	2.41	16.8
Correlation relationship, %		14.5	22.8	11.0

Note: * A – Share of Internet users in regional population; B – Share of Internet users with the purpose of interaction with public authorities; C – Share of Internet users with the purpose of study and education.

Table 5. Analytical grouping by share of industrial sector value added in GRP

Source: Authors' calculations based on the State Statistical Service of Ukraine (n.d.).

Groups by share of industrial sector value added in GRP, %	Regions	A	B	C
9.80-17.82	Kyiv city, Chernivtsi, Odesa, Ternopil, Zakarpattia, Volyn, Kherson, Khmelnytskyi			
17.82-25.84	Luhansk, Zhytomyr, Kirovohrad, Kyiv, Lviv, Chernihiv, Vinnytsia, Mykolaiv, Sumy, Rivne, Cherkasy			
25.84-33.86	Kharkiv, Ivano-Frankivsk	X	X	X
33.86-41.88	Zaporizhzhia			
41.88-49.90	Dnipropetrovsk, Poltava, Donetsk			
Between-group variation δ_x^2		6.79	0.32	1.74
General variation σ^2	X	48.5	2.41	16.8
Correlation relationship, %		37.4	32.2	36.6

Table 6. Analytical grouping by industrial sector value added per capita

Source: Authors' calculations based on the State Statistical Service of Ukraine (n.d.).

Groups by industrial sector value added per capita, UAH	Regions	A	B	C
4,481.0-14,588.7	Chernivtsi, Zakarpattia, Ternopil, Kherson, Luhansk, Odesa, Khmelnytskyi, Volyn, Zhytomyr, Rivne, Kirovohrad, Chernihiv, Sumy, Vinnytsia			
14,588.7-24,696.4	Mykolaiv, Lviv, Ivano-Frankivsk, Cherkasy, Kyiv, Kharkiv			
24,696.4-34,804.1	Kyiv city, Zaporizhzhia	X	X	X
34,804.1-44,911.8	Donetsk, Dnipropetrovsk			
44,911.8-55,019.5	Poltava			
Between-group variation δ_x^2		16.3	0.59	1.79
General variation σ^2	X	48.5	2.41	16.8
Correlation relationship, %		58.0	32.6	49.4

sector for digital technologies implementation. It makes it possible to assess the impact on regional digitalization (Table 7).

The asymmetric distribution of the digital development in regions in all four groups indicates remote prospects for ensuring the alignment of digital capabilities in relation to the grouping features.

Correlation of relations with analytical grouping by GDP per capita demonstrates a weak link between the level of income in the regions and the level of digital penetration. This indicates the generally low level of digital technology development and multidimensional spatial inequality in Ukraine.

Table 7. Analytical grouping by manufacturing value added per capita

Groups by manufacturing value added per capita, UAH	Regions	A	B	C
2,500.6-6,073.2	Chernivtsi, Zakarpattia, Luhansk, Ternopil, Kherson, Khmelnytskyi			
6,073.2-9,645.9	Rivne, Ivano-Frankivsk, Zhytomyr, Odesa, Kirovohrad, Chernihiv, Sumy, Volyn, Lviv, Mykolaiv			
9,645.9-13,218.6	Kharkiv, Vinnytsia	X	X	X
13,218.6-16,791.2	Cherkasy, Kyiv, Kyiv city, Poltava			
16,791.2-20,363.9	Donetsk, Zaporizhzhia, Dnipropetrovsk			
Between-group variation δ_x^2		6.48	1.77	0.47
General variation σ^2	X	48.5	2.41	16.8
Correlation relationship, %		36.5	32.5	44.3

As an example, significant differences in the country's mobile Internet coverage can be considered. Even though the 4G technology has long been launched in Ukraine, the country lags many years behind the high-income countries by mobile Internet coverage. Comparing the density of coverage with France, it is evident that Ukraine does not reach 20% of the level of this European country (Nekrasov, 2018). The smallest coverage is observed in the northern, central, southwestern, and southeastern regions. The western regions are most covered by the mobile Internet – Lviv, Ivano-Frankivsk, Zakarpattia, and Chernivtsi. The low population density in rural areas, as well as the complexity of frequency distribution procedures, are the barriers to the slow promotion of mobile Internet communications.

At the same time, a more significant grouping feature is the development of industry and the level of its added value in regional income. By the share of the gross value added of the industrial sector in the GRP, the correlation between both the Internet usage indicator in general and the indicators of Internet use for training and interaction with authorities demonstrates that this grouping feature explains about a third of the digital inequality of the regions. Similar results are observed in the analytical grouping by manufacturing value added per capita. However, this feature explains the 44.3% group variation of the share of Internet users with the purpose of study and education.

The indicator of industrial sector value added per capita demonstrated significant results. It explains 58% of the intergroup variation. Suppose one looks at the regional composition of each group.

In that case, one will observe that, with the deepening of industrial processing and the expansion of the industrial sector in the structure of regional gross added value, the average share of those who use the Internet increases. The maximum level of users (81.4%) is typical for Kyiv city, and in the third and fourth groups, the average level of users is 76.4% and 77.3%. In addition, the industrial sector value added per capita also explains nearly 50% of the intergroup variation of Internet users with the purpose of study and education. At the same time, the variation in the number of pupils of secondary schools per 100,000 population is low. The influence of industrial sector development on the capabilities of e-governance and digital means of interaction with the government in the regions is weak (only by 32.6%). The generally low-income level and property stratification within the regions (coefficient of variation is 37.3%) is also the reason for unequal access to digital technologies.

A share of populations with the average monthly per capita equivalent total income below the current subsistence level in 2018 varies – from 16.4% in Kyiv city to 42.5% in Kherson region; the overall variation of the indicator constitutes 25.1%. Such differences also cause the redistribution of household budgets not in favor of digital communications but to more urgent needs. The trend of interregional property stratification can be described as negative since in 2016, the variation was 14.4%.

Overcoming these trends requires the development of comprehensive measures to digitalize the economy to increase readiness for the challenges of national and regional development in the face of global instability.

4. DISCUSSION

Digital inequality and lag of Ukraine and its regions behind the pan-European digitalization trends result from many historical, economic, geographical, and social determinants. The regional digitalization development differentiation criteria explored in this research had, unlike those before (Ding et al., 2022; Song et al., 2019; Zhang et al., 2018; UNCTAD, 2006), demonstrated that the income factor can explain only a half of the variation of Internet users. Other 50% are covered by several unaccounted causes, such as landscape influencing ICT infrastructure (Kolodiziev et al., 2018) and population density (Beynon-Davies & Hill, 2007).

It is also possible to highlight some limitations of the sample data used in the study. The representativeness of the sample in each region is not in doubt, but the high probability of systematic observation errors cannot be discarded. The lack of reliable indicators of digitalization in the regional context, in addition to the results of statistical surveys of households in Ukraine, does not leave any choice of research data.

However, the study results indicate that the trend in narrowing the digital divide is positive. At the same time, the lack of digital skills, barriers to access the digital technologies due to the low households' incomes, weakness of the cybersecurity system, the spread of artificial intelligence technologies, active ICT sector development are still the challenges for a comprehensive state policy.

World Bank Group (2016) proposed implementing a bilateral digitalization policy aimed at supply and demand. For the first component of such a policy, it is recommended to analyze the supply chains of Internet services from the point of their entry into the geographical space of the country to a specific end-user. Therefore, it can be recommended to support market competition and provide public-private partnership projects and market failures regulation of mobile Internet communications (remote regions, economically unattractive markets) through infrastructure sharing, the latest technological solutions for providing broadband Internet in rural areas. Moreover, it is vital to ensure rational management of frequency distribution and other resources, and regulate price gaps. It is also necessary to identify which regions of the country are moving at a pre-emptive pace in the digital transformation of community life, and which are stagnating and need additional incentives.

On the demand side, it is proposed to consider and address the issues of censorship and filtering of Internet content, which threaten to slow down the prospects of digitalization of communications. Cybersecurity should be ensured by the balance between network security and the protection of individual rights, as well as contribute to the protection of personal data, which will increase confidence in the Internet. The Tunis Agenda for the Information Society (WSIS, 2005) and FAO (2021) paid a special role to increase funding for access to ICT. In the regional context, it can be recommended to expand cooperation and multilateral partnerships, especially to create the regional backbone infrastructure.

Regarding the identified impact of the regional industrial development on the level of digital inequality in Ukraine, it is recommended to stimulate the production of medium- and high-tech products and introduce the smart city/territory initiatives in the framework of sustainable development (Zharova, 2019). Furthermore, investments in new technologies will ensure higher manufacturing value added in the regions and shape preconditions for digital technologies penetration.

Initiatives of large companies implementing social responsibility projects can also influence the reduction of the digital divide. Thus, Huawei's TECH4ALL initiative ensuring digital accessibility to contribute SDGs (Shen, 2020) launched many educational programs for adolescents and students and created a sustainable talent ecosystem. Multilateral partnership in these matters becomes a critical component.

CONCLUSION

The idea of the study was to explore the link between the regional digital divide as the emerging problem for sustainable development and the level of economic, in particular industrial, development, and to generalize and find efficient measures of digitalization in lagging regions.

The analysis of regional variation of digital and socio-economic development indicators showed an overall reduction in stratification for 2010–2019, but growth and relatively high rates of variation in individual positions: e-mailing; reading online/downloading newspapers, magazines; as well as on GRP per capita and share of industrial sector value added in GRP.

The analytical grouping proved that the value added of the industrial sector plays a greater role than the total gross regional product in explaining regional digital inequality. It makes a significant contribution to the overall level of Internet access (58.0%). However, a less significant contribution is made to ensure access to study and education (49.4%). The gross value added closely correlates with the share of the industrial sector in the GRP and the depth of raw materials processing. Thus, the policies aimed at industrial technologies development can cause positive effects in ensuring the digital alignment of lagging regions.

International experience and recommendations of international organizations for digital transformation and overcoming digital inequality suggest both supply-side policy (investments and public financial aid for the development of technological infrastructure, compensation of market failures through price regulation, distribution of frequencies for mobile Internet, support of market competition), and demand-side policy instruments (cybersecurity, personal data protection policies), which can be implemented in Ukraine.

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