



GDP IMPACT ON THE DIGITAL ECONOMY IN EUROPEAN UNION COUNTRIES

Roman Machuga

Faculty of Economic Sciences
University of Warmia and Mazury in Olsztyn
ORCID: <https://orcid.org/0000-0002-5333-494X>
e-mail: roman.machuga@uwm.edu.pl

JEL Classification: C43, D83, L86.

Key words: DESI, digital economy, information and communication technologies, European Union.

Abstract

This article explores issues relating to the development of the digital economy in the countries of the European Union. Its aim is to assess the impact of a country's GDP on its DESI index. In this study, the research problem involves finding answers to the following questions: 1) Why does the development of the digital economy in different EU countries show such a substantial variation? 2) Which DESI index indicators have the greatest impact on its final score? 3) Does the overall development of the domestic economy have an impact on the development of its information society? The research conducted with these goals in mind warrants the conclusion that the pace of development of the digital economy in the less developed EU countries is higher than in the leader countries. Furthermore, it has been found that the indicators within the "4 Digital public services" and "1 Human capital" dimensions have the greatest impact on the DESI index. The direct influence of GDP per capita on the DESI index has been demonstrated experimentally. In contrast, the assumption that the growth rate of GDP and the share of the ICT sector in GDP correlates with the development of the digital economy and information society has not been confirmed.

WPLYW PKB NA GOSPODARKE CYFROWA W KRAJACH UNII EUROPEJSKIEJ

Roman Machuga

Wydział Nauk Ekonomicznych
Uniwersytet Warmińsko-Mazurski w Olsztynie

Kody JEL: C43, D83, L86.

Słowa kluczowe: DESI, gospodarka cyfrowa, technologie informacyjno-komunikacyjne, Unia Europejska.

How to cite: Machuga, M. (2023). GDP Impact on the Digital Economy in European Union Countries. *Olsztyn Economic Journal*, 18(2), 127-140. <https://doi.org/10.31648/oj.10105>

Abstrakt

W artykule postawiono pytania dotyczące rozwoju gospodarki cyfrowej krajów Unii Europejskiej. Celem artykułu jest identyfikacja wpływu PKB kraju na jego indeks DESI. Problemem badawczym opracowania jest znalezienie odpowiedzi na pytania: dlaczego istnieje tak duże zróżnicowanie w rozwoju gospodarki cyfrowej w różnych krajach Unii Europejskiej?; jakie wskaźniki indeksu DESI mają największy wpływ na jego końcową wartość?; czy ogólny rozwój gospodarki kraju ma wpływ na rozwój jego społeczeństwa informacyjnego? Wyniki przeprowadzonych badań pozwalają stwierdzić, że tempo rozwoju gospodarki cyfrowej w krajach UE mniej rozwiniętych jest większe od krajów-liderów. Ponadto ustalono, że największy wpływ na indeks DESI mają wskaźniki wymiarów „4 Digital public services” i „1 Human capital”. Eksperymentalnie potwierdzono bezpośredni wpływ PKB na mieszkańca na indeks DESI. Założenia natomiast o istnieniu związku między tempem wzrostu PKB i udziałem sektora ICT w PKB a rozwojem gospodarki cyfrowej i społeczeństwa informacyjnego nie potwierdzono.

Introduction

Since 2014, the assessment of the digital economy and development of the information society in EU countries has relied on the Digital Economy and Society Index (DESI). Originating with the European Commission, the index was introduced as a tool to monitor the progress of digitalization in various sectors of the national economy of the EU Member States. “At present, DESI serves to monitor 32 digital maturity indicators, spanning four areas: Digital Competence, Digital Infrastructure, Digital Transformation of Businesses, Digitalization of Public Services” (*Wskaźnik DESI jako miernik...*, 2023). All these areas are taken into account while compiling detailed annual reports which describe the progress of digital transformation in EU countries. Chronological data from the reports suggests the need for accelerated change, while the Member States should become more involved in the digitalization of their digital economy. The DESI index shows significant variation in the development of information societies in the countries of the European Union. Finland, Denmark, Sweden, and the Netherlands invariably lead the 27 states, whereas those falling behind include Romania, Greece, Bulgaria and Poland (Fig. 1).

In order to reduce the existing gap between the digitally developed countries and the underperformers, including Poland, it is necessary to “[...] carry out reforms, improve the business environment, encourage investment in digital technologies, promote skills and modernize the infrastructure. The aforementioned actions should be implemented in line with the provisions of the jointly adopted European Declaration on Digital Rights and Principles for the Digital Decade” (*Wskaźnik DESI jako miernik...*, 2023).

The research problem of this study is to find answers to the following questions:

– why does the development of the digital economy in different EU countries show such a substantial variation?

– which DESI index indicators have the greatest impact on the final score?
 – does the overall development of the domestic economy have an impact on the development of its information society?

Finding answers to the above questions will make it possible to understand the causes behind the existing discrepancies in the development of the digital economy and advance measures to improve the position of underperforming countries, including Poland. The answers will also help to achieve the objectives set by

countries	2017	2018	2019	2020	2021	2022
Austria	12	12	11	13	10	10
Belgium	13	13	15	11	14	17
Bulgaria	↓ 26	↓ 26	↓ 26	↓ 26	↓ 26	↓ 27
Croatia	20	20	20	20	20	21
Cyprus	22	23	23	24	22	21
Czechia	19	19	19	19	19	20
Denmark	↑ 2	↑ 3	↑ 2	↑ 2	↑ 2	↑ 2
Estonia	8	7	9	9	9	9
European Union	17	17	17	18	15	15
Finland	↑ 1	↑ 1	↑ 1	↑ 1	↑ 2	↑ 1
France	16	16	16	16	17	12
Germany	18	18	18	17	12	13
Greece	↓ 27	↓ 27	↓ 27	↓ 27	↓ 27	↓ 26
Hungary	23	24	24	23	24	23
Ireland	7	6	8	7	5	5
Italy	24	22	21	21	21	19
Latvia	10	11	12	12	16	18
Lithuania	11	10	10	10	13	14
Luxembourg	5	5	5	6	6	8
Malta	6	8	6	5	8	6
Netherlands	↑ 4	↑ 4	↑ 4	↑ 4	↑ 3	↑ 3
Poland	↓ 25	↓ 25	↓ 25	↓ 25	↓ 25	↓ 25
Portugal	15	15	14	14	18	16
Romania	↓ 28	↓ 28	↓ 28	↓ 28	↓ 28	↓ 28
Slovakia	21	21	22	22	23	24
Slovenia	14	14	13	15	11	11
Spain	9	9	7	8	7	7
Sweden	↑ 3	↑ 2	↑ 3	↑ 3	↑ 4	↑ 4

Fig. 1. Ranking of EU countries in the DESI index

Source: own elaboration based on *Digital Economy and Society Index...* (2022b).

the European Parliament with respect to the digital economy and information society in EU countries, published in the policy programme entitled *The Path to the Digital Decade*. According to the latter, the digital targets include, e.g. (Decyzja Parlamentu Europejskiego..., 2022, p. 15, 16):

„1) A digitally skilled population and highly skilled digital professionals, with the aim of achieving gender balance, where:

- at least 80% of those aged 16-74 have at least basic digital skills;
- at least 20 million ICT specialists are employed within the Union while promoting the access of women to this field and increasing the number of ICT graduates [...];

2) the digital transformation of businesses, where:

- at least 75% of Union enterprises have taken up one or more of the following, in line with their business operations: (i) cloud computing services; (ii) big data; (iii) artificial intelligence;
- more than 90% of Union SMEs reach at least a basic level of digital intensity [...];

3) the digitalisation of public services, where:

- there is 100% online accessible provision of key public services and, where relevant, it is possible for citizens and businesses in the Union to interact online with public administrations;
- 100% of Union citizens have access to their electronic health records;
- 100% of Union citizens have access to secure electronic identification (eID) means that are recognised throughout the Union, enabling them to have full control over identity transactions and shared personal data”.

Given the above, the enquiry undertaken here is highly relevant and may contribute to achieving the digital targets facing the Member States.

The impact of the DESI index on the economies of EU countries has often been addressed in scientific investigations. For instance, M. Olczyk and M. Kuc-Czarnecka have analysed the possibilities of improving the structure of the DESI index as well as its impact on the GDP of a country. The authors confirmed that the growth of the DESI index has a positive impact on GDP per capita. In their opinion, the growth of the digital economy will promote direct economic growth for the country as a whole (Olczyk & Kuc-Czarnecka, 2022). The effect of particular DESI index indicators on a country's GDP per capita has been examined in yet another publication, whose authors argue that such a relationship does exist and, moreover, proves particularly significant with respect to citizens' use of online services by citizens and digital technology integration by tech enterprises (Parra *et al.*, 2021). Based on those findings, it is presumed in this paper that an increase in GDP per capita may boost the development of the digital economy. Along with the impact of GDP, it would be worthwhile to analyse how its growth rate affects the characteristics of the development of the digital economy. Investigating such relationships might serve to justify the differentiation of the DESI index for various EU countries.

A study by Ł. Arendt focuses on the relationships between ICT and GDP growth in the countries of Central and Eastern Europe. The author also examines various indices which serve to measure the development of the digital economy and information society. The inquiry confirms the positive impact of ICT capital on the GDP growth of a country (Arendt, 2015). Furthermore, the existence of a link between a country's ICT sector and its economic growth is highlighted by a team of authors from Uzbekistan. Specifically, their study demonstrates that an increase in ICT sector indicators is associated with an increase in GDP dynamics (Ishnazarov *et al.*, 2021). A similar conclusion was reached by UAE authors in their study on the impact of investment in the ICT sector on economic growth (*Assessing the Impact of ICT...*, 2023). A potential link between the share of a country's ICT sector in its GDP may also be inferred from the fact that pertinent statistical data were collected between 2009 and 2020 by Eurostat (*Percentage of the ICT sector...*, 2023). The research conducted to date offers grounds for the assumption concerning the actual impact of ICT sector size in GDP on the DESI index.

A number of other publications in recent years have also been concerned with the impact of the DESI index on various aspects of the national economy. For example, O. Başol and E.C. Yalçın found that an increase in the DESI brought about a rise in the employment rate and personal earnings, both of which constitute positive labour market indicators; simultaneously, it reduced negative labour market indicators such as long-term unemployment rate and labour market insecurity. A higher level of digitalization in EU countries in 2018 contributed to an improvement in labour market indicators (Başol & Yalçın, 2021). The existence of a link between consumption, unemployment and the DESI index was asserted by yet another team of authors, who showed that a 1% increase in the consumption index sees a corresponding DESI increase of about 0.2, while when unemployment increases by 1%, DESI drops by approximately 0.2 (Stavytskyy *et al.*, 2021).

Thus, previous research confirms that the development of a digital economy and information society is indeed reflected in a country's overall economic development and GDP growth. Consequently, there are valid reasons to assume that the economic development of a country influences the development of its e-economy and information society.

Based on the analysis of previous scientific publications and their findings, the author of the current study considers it reasonable to formulate the following *objective* of the paper: to identify the impact of a country's Gross Domestic Product on its position in the DESI ranking. In order to accomplish that objective, it is necessary to verify three research hypotheses:

- H1. A country's GDP per capita has an impact on its DESI index ranking.
- H2. A country's real GDP growth rate affects its DESI index.
- H3. The share of the ICT sector in a country's GDP affects its DESI index.

Research Methodology

The research relies on statistical data from the Eurostat portal. The data were subjected to statistical analysis involving Pearson correlation. The research spans the period from 2017 to 2022, while its territorial scope is confined to the countries of the European Union.

In order to accomplish the objective of the study and verify the research hypotheses, the following steps were taken:

- analysis and characterization of the structure of the DESI index;
- determination of the weights of its individual indicators and identification of those which demonstrate the greatest impact;
- analysis of the growth dynamics of the DESI index for different countries;
- statistical analysis of the collected statistical data;
- verification of research hypotheses;
- formulating conclusions and suggestions.

Based on an analysis of scientific publications (Żurkowski, 2014; Siedlecka, 2001; Kukuła, 2003), the following *r*-Pearson correlation coefficient scale was adopted for the purposes of assessing the strength of correlative relationships in the study:

- $0 \leq r \leq 0.3$ – none or very weak;
- $0.3 < r \leq 0.5$ – moderate;
- $0.5 < r \leq 0.7$ – strong;
- $0.7 < r \leq 1$ – very strong.

In order to assess the statistical significance of the *r*-Pearson correlation coefficient, *p* was set at ≤ 0.05 . Statistical analyses were carried out using IBM SPSS Statistics software (v. 29.0.0.0), while source data modelling and visualizations were obtained by means of Visio Professional 2013 and Power BI Desktop from Microsoft (v. 2.124.1052.0, December 2023).

Results

The DESI index is currently used to assess the state of the digital economy and the development of information society in the countries of the European Union. As already noted, there are evident leaders and countries which clearly fail to keep up the pace. Finland, for instance, qualifies as the former, while Romania ranks lowest on the list. Although Poland does not perform very poorly, it has been in 25th place out of 28 countries for several years (Fig. 1). Figure 2 compares the DESI index for Finland, Poland and the European Union average. In 2017-2022, Finland's score increased 1.45 times (by 31.2%), European Union's 1.55 times (by 35.6%) and Poland's 1.63 times (by 38.7%). Such a rate of growth is indicative of positive dynamics among the less digitally developed countries

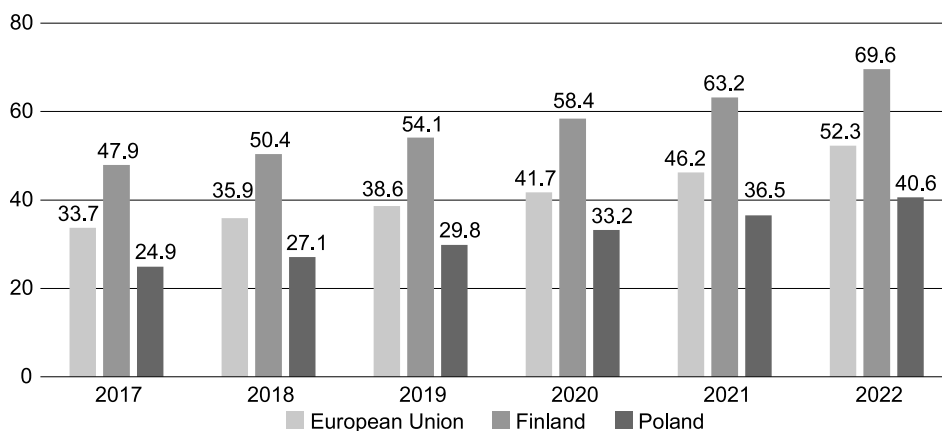


Fig. 2. Comparison of the DESI index for Finland, European Union and Poland
Source: own elaboration based on *Digital Economy and Society Index...* (2022b).

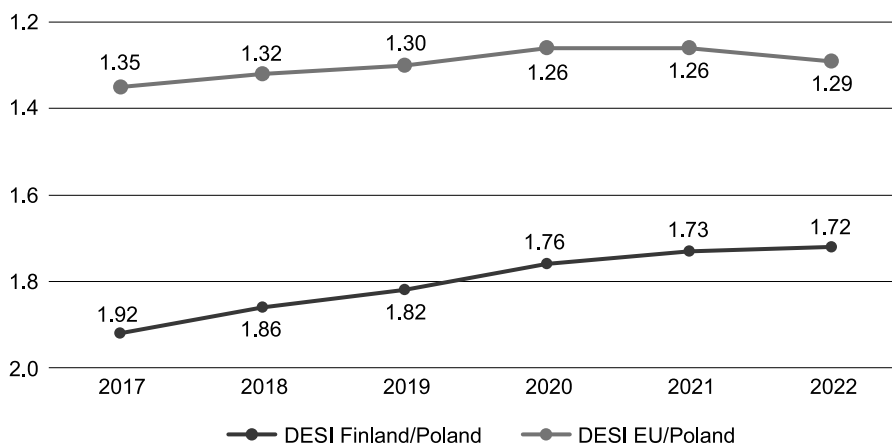


Fig. 3. DESI index quotient for Finland/Poland and EU/Poland
Source: own elaboration based on *Digital Economy and Society Index...* (2022b).

compared with the leaders. The same trend may be seen in the data presented in Figure 3, which shows a definite reduction in the gap between Poland and Finland.

Positive trends may also be observed in other EU countries, as the DESI index scores increased year-on-year for all Member States, with annual growth ranging from 3.88% to 17.29% (Fig. 4). The visualization in Figure 4 demonstrates highly dynamic growth of the digital economy index in the underperforming countries in comparison with the leaders shown in Figure 1. For example, in the analysed period (2017-2022), the annual growth of the DESI index for Finland and Sweden did not exceed 10%. The two other record-breakers – Denmark and

the Netherlands – exceeded 10% growth only in 2021/2020 but failed to reach that threshold in other years. In contrast, in the countries marked as underperformers in Figure 1, the growth in the final years exceeded 10% (e.g. Romania – 10.30% in 2022/2021; Greece – 15.16% in 2021/2020 and 16.49% in 2022/2021; Bulgaria – 13.35% in 2022/2021; Poland – 10.30% in 2020/2019) (Fig. 4). These figures clearly show an increase in the growth rate of the digital economy and information society in the countries which apparently fare less well.

countries	Index growth in %				
	2018/2017	2019/2018	2020/2019	2021/2020	2022/2021
Austria	5.36	6.77	5.48	13.68	7.61
Belgium	6.05	4.92	9.58	5.31	7.14
Bulgaria	7.25	8.09	5.94	8.67	13.35
Croatia	5.54	8.30	5.24	14.09	9.40
Cyprus	↓ 4.11	7.09	7.41	11.63	↑ 17.29
Czechia	6.90	8.02	5.99	8.79	11.76
Denmark	4.56	6.44	7.02	14.21	↓ 5.90
Estonia	6.00	5.58	5.06	7.70	5.96
European Union	6.15	7.04	7.27	9.81	11.63
Finland	4.98	6.96	7.33	7.50	9.25
France	5.84	8.94	7.22	7.38	13.89
Germany	5.24	7.98	8.84	10.60	11.01
Greece	4.93	7.87	7.43	↑ 15.16	16.49
Hungary	6.18	6.40	10.19	7.44	11.54
Ireland	6.26	5.57	8.11	11.03	8.94
Italy	7.88	↑ 10.98	6.51	10.09	17.06
Latvia	5.05	↓ 3.88	6.99	↓ 4.49	7.20
Lithuania	7.86	6.19	5.53	5.02	10.79
Luxembourg	4.36	4.00	6.78	6.96	6.49
Malta	4.90	7.59	7.90	5.38	10.56
Netherlands	5.16	4.83	7.61	12.33	7.44
Poland	↑ 8.11	8.90	↑ 10.30	9.12	9.91
Portugal	6.29	6.10	6.97	5.49	9.67
Romania	6.42	7.33	9.55	9.91	10.30
Slovakia	6.03	4.72	8.10	9.41	8.08
Slovenia	5.73	7.39	↓ 4.73	10.51	10.12
Spain	6.57	7.82	5.39	9.29	9.81
Sweden	6.22	6.18	6.80	7.84	7.25

Fig. 4. Comparison of DESI index growth in successive years
Source: own elaboration based on *Digital Economy and Society Index...* (2022b).

The structure of the DESI index in 2022 involved a division of the thirty-two indicators into four dimensions and ten sub-dimensions. The weight of each dimension is equal and accounts for 25%. The sub-dimensions, on the other hand, have a varied influence on their corresponding dimension. According to the authors of the DESI index, this impact ranges from 10% to 100% (Fig. 5). The impact of individual indicators and each sub-dimension was found equally important and, therefore, they were assigned equal weights within the respective sub-dimension (*Digital Economy and Society Index...*, 2022a, p. 12).

Following calculations, it was determined that the weight of the individual indicators ranges from 1.25% to 5.00%. Factors in the dimensions “4 Digital public services” and “1 Human capital” (sub-dimension “1a Internet user skills”) carry the highest weight (4.17-5.00%), whereas the lowest (1.25-2.08%) was allocated to the dimensions “3 Integration of digital technology” (sub-dimension “3c e-Commerce”) and “2 Connectivity” (sub-dimension “2a Fixed broadband take-up”) (Tab. 1). Analogous conclusions may be drawn from the visualizations in Figure 6, which demonstrate the contribution of individual dimensions to the structure of the DESI index for Finland, European Union and Poland.

Table 1

DESI index indicators by weight

Indicators	Weights [%]
4a1 e-Government users; 4a2 Pre-filled forms; 4a3 Digital public services for citizens; 4a4 Digital public services for businesses; 4a5 Open data	5.00
1a1 At least basic digital skills; 1a2 Above basic digital skills; 1a3 At least basic digital content creation skills	4.17
3a1 SMEs with at least a basic level of digital intensity	3.75
2c1 5G spectrum; 2c2 5G coverage; 2c3 Mobile broadband take-up	3.33
1b1 ICT specialists; 1b2 Female ICT specialists; 1b3 Enterprises providing ICT training; 1b4 ICT graduates	3.13
2b1 Fast broadband (NGA) coverage; 2b2 Fixed Very High Capacity Network (VHCN) coverage	3.13
2d1 Broadband price index	2.50
3b1 Electronic information sharing; 3b2 Social media; 3b3 Big data; 3b4 Cloud; 3b5 AI; 3b6 ICT for environmental sustainability; 3b7 e-Invoices	2.50
2a1 Overall fixed broadband take-up; 2a2 At least 100 Mbps fixed broadband take-up; 2a3 At least 1 Gbps take-up	2.08
3c1 SMEs selling online; 3c2 e-Commerce turnover; 3c3 Selling online cross-border	1.25

Source: own elaboration based on *Digital Economy and Society Index* (2022a, p. 4, 12).

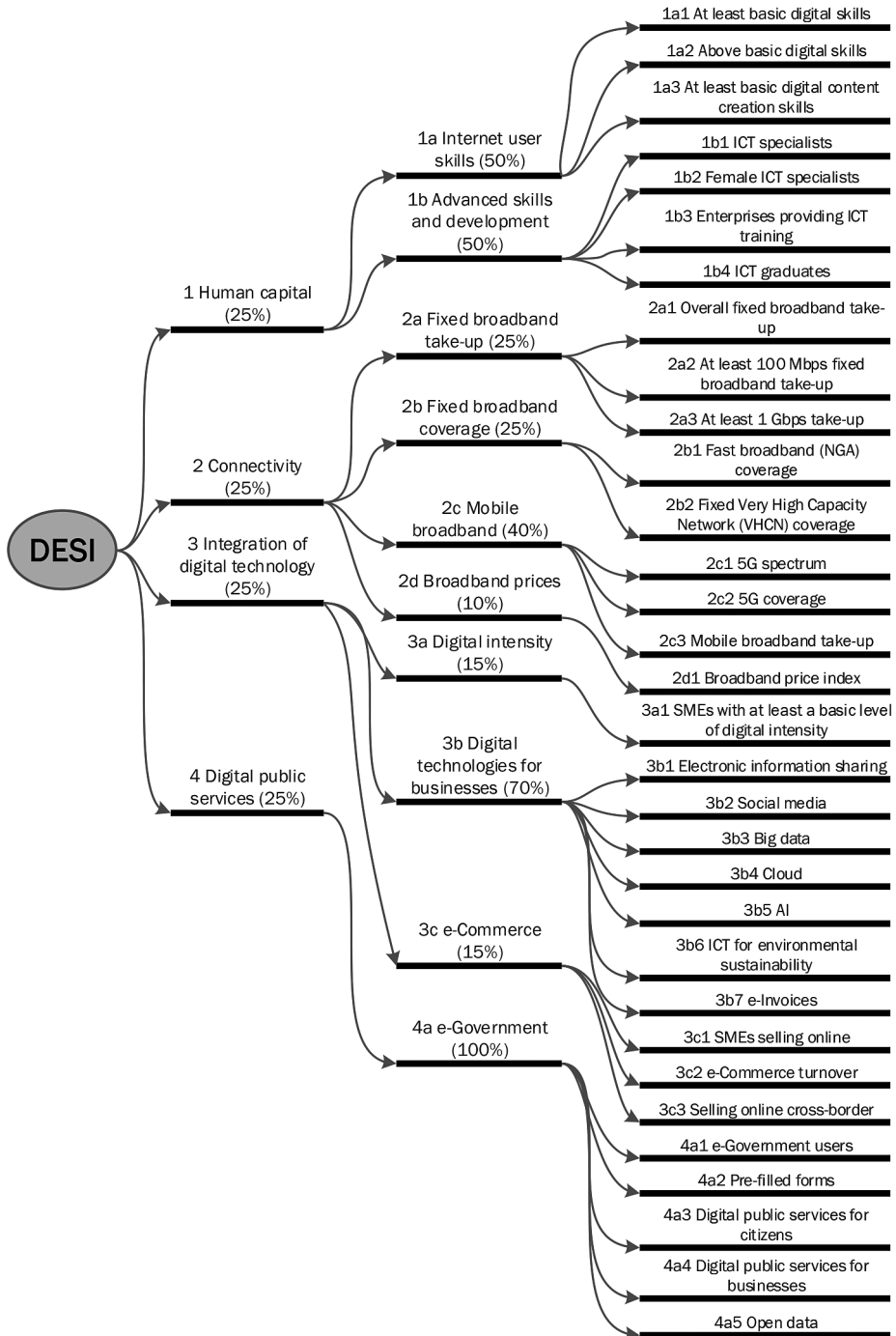


Fig. 5. Structure of the DESI index

Source: own elaboration based on *Digital Economy and Society Index* (2022a, p. 4, 12).

Based on the calculated weights in Table 1, it may be concluded that in order to increase the DESI index, particular attention should be paid to the highest-weight indicators in the dimensions “4 Digital public services” and “1 Human capital” (Fig. 6). Their increase will bear most substantially on the direct increase of the DESI index of all Member States.

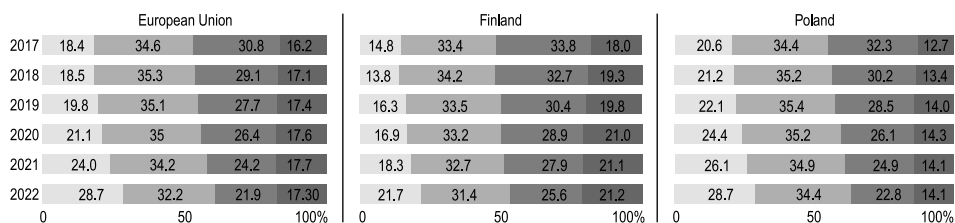


Fig. 6. Percentage structure of the DESI index for Finland, the European Union and Poland
Source: own elaboration based on *Digital Economy and Society Index...* (2022b).

The following criteria were selected for statistical analysis in this study:

- the DESI index (*Digital Economy and Society Index...*, 2022b);
- actual growth rate of a country’s GDP (*Real GDP growth...*, 2023);
- share of the ICT sector in a country’s GDP (*Percentage of the ICT sector...*, 2023);
- country’s GDP per capita (*GDP per capita...*, 2023).

Statistical analysis of the above criteria was carried out in the IBM SPSS Statistics programme. As a result of this analysis, a correlation table was prepared, including the values of the r -Pearson correlation coefficient and its statistical significance p (Tab. 2).

Table 2

Results of correlation analysis

Specification		2017	2018	2019	2020	2021	2022
Real GDP growth rate	r -Pearson correlation	-0.22	-0.407	-0.502	0.186	-0.161	-0.401
	statistical significance p	0.261	0.032	0.007	0.343	0.413	0.035
Share of the ICT sector in GDP	r -Pearson correlation	-0.273	-0.037	-0.183	-0.035	–	–
	statistical significance p	0.16	0.85	0.352	0.861	–	–
GDP per capita	r -Pearson correlation	0.582	0.574	0.553	0.565	0.564	0.539
	statistical significance p	0.001	0.001	0.002	0.002	0.002	0.003

Source: own elaboration.

In Table 2, cells with statistical significance $p > 0.05$ are highlighted in red. The calculations demonstrate that the relationship between the DESI index and the share of the ICT sector in GDP is not statistically significant, i.e. changes in that share do not contribute to changes in the index. The correlation of real GDP growth rate was statistically significant in only three years: 2018, 2019 and 2022. For these years, the correlation is moderate, with the coefficient $r < 0$. This means that the correlation is inverse: a higher growth rate may cause a decrease in the DESI index, and, conversely, a decrease in the GDP growth rate will positively affect the DESI. Because the correlation of this indicator is statistically significant only in three years and insignificant in the remainder, it is not possible to state conclusively that there is a relationship between the GDP growth rate and the DESI index.

The third analyzed criterion (GDP per capita) has a positive, statistically significant correlation with the DESI index ($p \leq 0.003$), whereby the relationship itself is strong (Tab. 2). It would follow that an increase in GDP per capita translates into higher DESI index and, conversely, a drop in GDP results in a decrease in the DESI.

Summary and Conclusions

The statistical tests carried out as part of this study enable verification of the adopted research hypotheses (Tab. 3). Hypothesis H1 was verified positively, and hypotheses H2 and H3 were verified negatively. Such outcomes confirm that GDP per capita has an impact on a country's DESI index. On the other hand, the assumption that there exists a relationship between GDP growth rate, the share of the ICT sector in GDP and the development of digital economy and information society was rejected.

Table 3

Verification of research hypotheses

Hypothesis	r -Pearson correlation coefficient and statistical significance		Verification	
H1. GDP per capita of a country has an impact on its DESI index score	$0.539 \leq r \leq 0.582$ $p \leq 0.003$		positive	
H2. Real GDP growth rate of a country has an impact on its DESI index	years: 2017, 2018, 2021	$p > 0.05$	partially negative	negative
	years: 2018, 2019, 2022	$-0.502 \leq r \leq -0.401$ $p \leq 0.035$	partially positive	
H3. Share of the ICT sector in the GDP of a country has an impact on its DESI index	$p > 0.05$		negative	

Source: own elaboration.

The research conducted as part of this study enables the following conclusions to be drawn:

1. The rate of development of the digital economy in the less developed EU countries is higher than in the leading countries.
2. The indicators within the dimensions “4 Digital public services” and “1 Human capital” have the greatest impact on the DESI index.
3. GDP per capita has a direct impact on a country’s DESI index.
4. The assumption that there is a relationship between the growth rate of GDP, the share of the ICT sector in GDP and the development of digital economy and information society was not confirmed.

In the author’s opinion, prospective research may include further inquiries into the structure of the DESI index and the impact of GDP on its individual indicators.

Translated by: Joanna Jensen, Biuro Tłumaczeń OSCAR

References

- Arendt, L. (2015). The digital economy, ICT and economic growth in the CEE countries. *Olsztyn Economic Journal*, 10(3), 247-262. <https://doi.org/10.31648/oej.3150>.
- Assessing the Impact of ICT Investments on Growth*. (2023). International Monetary Fund. Middle East and Central Asia Dept. Retrieved from <https://www.elibrary.imf.org/view/journals/002/2023/224/article-A003-en.xml> (18.03.2024).
- Başol, O., & Yalçın, E.C. (2021). How does the digital economy and society index (DESI) affect labor market indicators in EU countries? *Human Systems Management*, 40(4), 503-512. <https://doi.org/10.3233/HSM-200904>.
- Decyzja Parlamentu Europejskiego i Rady (UE) 2022/2481 z dnia 14 grudnia 2022 r. ustanawiająca program polityki „Droga ku cyfrowej dekadzie” do 2030 r. (2022). Dz. Urz. UE L 323/4, 19.12.2022. Retrieved from <https://www.gov.pl/web/ia/wskaznik-desi-jako-miernik-stopnia-cyfryzacji-panstw> (18.03.2024).
- Digital Economy and Society Index (DESI) 2022. Methodological Note*. (2022a). European Commission. Retrieved from <https://ec.europa.eu/newsroom/dae/redirection/document/88557> (16.03.2024).
- Digital Economy and Society Index (until 2022). Dataset Metadata*. (2022b). European Commission. Retrieved from <https://digital-decade-desi.digital-strategy.ec.europa.eu/api/v1/chart-groups/desi-2022/facts/> (17.03.2024).
- GDP per capita in PPS*. (2023). Eurostat. Retrieved from https://ec.europa.eu/eurostat/databrowser/view/tec00114__custom_10428577/default/table?lang=en (17.03.2024).
- Ishnazarov, A., Kasimova, N., Tosheva, S., & Isaeva, A. (2021). *ICT and Economic Growth: Evidence from Cross-Country Growth Modeling*. ICFNDS 2021: The 5th International Conference on Future Networks & Distributed Systems, p. 668-671. <https://doi.org/10.1145/3508072.3508204>.
- Kukuła, K. (2003). *Elementy statystyki w zadaniach*. Warszawa: Wydawnictwo Naukowe PWN.
- Olczyk, M., & Kuc-Czarnecka, M. (2022). Digital transformation and economic growth – DESI improvement and implementation. *Technological and Economic Development of Economy*, 28(3), 775-803. <https://doi.org/10.3846/tede.2022.16766>.
- Parra, J., Pérez-Pons, M.E., & González, J. (2021). Study Based on the Incidence of the Index of Economy and Digital Society (DESI) in the GDP of the Eurozone Economies. In S. Rodríguez González, A. González-Briones, A. Gola, G. Katranas, M. Ricca, R. Loukanova, & J. Prieto (Ed.), *Distributed Computing and Artificial Intelligence, Special Sessions, 17th International*

- Conference. DCAI 2020. Advances in Intelligent Systems and Computing*, vol. 1242. Springer, Cham. https://doi.org/10.1007/978-3-030-53829-3_16.
- Percentage of the ICT sector on GDP* (2023). Eurostat. Retrieved from https://ec.europa.eu/eurostat/databrowser/view/tin00074__custom_10428739/default/table?lang=en (17.03.2024).
- Real GDP growth rate – volume* (2023). Eurostat. Retrieved from https://ec.europa.eu/eurostat/databrowser/view/tec00115__custom_10428672/default/table?lang=en (17.03.2024).
- Siedlecka, U. (2001). Metody analizy korelacji i regresji. In S. Ostasiewicz, Z. Rusnak, & U. Siedlecka (Ed.). *Statystyka. Elementy teorii i zadania*, 331-358. Wrocław: Wydawnictwo Akademii Ekonomicznej im. Oskara Langego.
- Stavytskyy, A., Kharlamova, G., & Stoica, E.A. (2021). The Analysis of the Digital Economy and Society Index in the EU. *TalTech Journal of European Studies*, 9(3), 245-261. <https://doi.org/10.1515/bjes-2019-0032>.
- Wskaźnik DESI jako miernik stopnia cyfryzacji państw.* (2023). Gov.pl. Retrieved from <https://www.gov.pl/web/ia/wskaznik-desi-jako-miernik-stopnia-cyfryzacji-panstw> (18.03.2024).
- Żurkowski, A. (2014). Analiza wpływu czynników społeczno-gospodarczych na wielkość kolejowych przewozów pasażerskich w Polsce. *TTS Technika Transportu Szybnego*, 9, 10-14.