UDC 339.137:004.9(477)]:330.143.2
JEL: C10; C12; L86
DOI: https://doi.org/10.32983/2222-4459-2025-7-106-115

CORRELATION ANALYSIS OF COMPETITIVENESS FACTORS AND CONTRIBUTION OF UKRAINE'S ICT SECTOR TO GDP AND GVA

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UDC 339.137:004.9(477)]:330.143.2
JEL: C10; C12; L86

Zavhorodnya E. O., Melnyk T. M., Shestak Ya. I. Correlation Analysis of Competitiveness Factors and Contribution of Ukraine's ICT Sector to GDP and GVA

The article examines the statistical relationships between the key factors of international competitiveness of Ukraine's ICT sector and its contribution to gross domestic product (GDP) and gross value added (GVA). In the context of digital transformation, the ICT sector is becoming an important driver of innovation and economic growth, especially for transition economies such as Ukraine. The aim of the study is to quantify the strength and direction of correlations between certain groups of competitiveness factors (ICT infrastructure, human capital, business environment, R&D, international integration) and economic indicators that characterise the role of the ICT sector in Ukraine's economy. The methodological basis of the study is the operationalisation of indicators, correlation analysis, time series analysis and visualisation of results. The empirical results show that there are strong positive correlations between the high level of ICT services exports, the development of ICT infrastructure, the share of ICT professionals in the employment structure, and the share of the ICT sector in Ukraine's GDP and GVA. Besides, a positive impact has been found for indicators characterising investments in education and science, the level of participation in international trade, and the number of scientific researches in ICTs. Conversely, a number of negative factors have been identified that limit the competitiveness and share of the ICT sector in Ukraine's economy, including low levels of innovation financing, regulatory instability, insufficient development of venture capital, cyber risks, and a high level of migration of ICT professionals abroad. The statistical testing of the hypotheses confirmed the significance of the identified links between the factors of international competitiveness of the ICT sector and the GDP and GVA of Ukraine. The practical significance of the study lies in the formation of an analytical basis for the development of a State policy to support the ICT sector, aimed at enhancing its role in the country's economic growth and strengthening Ukraine's position in the global ICT market.

Keywords: *competitiveness, ICT sector, ICT infrastructure, human capital, business and regulatory environment, R&D, international economic relations, correlation.*

Tabl.: *8.* ***Formulae:*** *5.* ***Bibl.:*** *12.*

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УДК 339.137:004.9(477)]:330.143.2
JEL: C10; C12; L86

Завгородня Є. О., Мельник Т. М., Шестак Я. І. Кореляційний аналіз факторів конкурентоспроможності та економічного внеску ІТ-сектора України у ВВП і ВДВ

У статті досліджено статистичні взаємозв'язки між ключовими факторами міжнародної конкурентоспроможності ІТ-сектора України та його внеском у валовий внутрішній продукт (ВВП) і валову додану вартість (ВДВ). У контексті цифрової трансформації ІТ-сектор стає важливим рушієм інновацій і економічного зростання, особливо для країн з перехідною економікою, таких як Україна. Метою дослідження є кількісна оцінка сили та напрямку кореляцій між визначеними групами факторів конкурентоспроможності (ІКТ-інфраструктура, людський капітал, ділове середовище, НДДКР, міжнародна інтеграція) та економічними показниками, що характеризують роль ІТ-сектора в економіці України. Методологічну основу дослідження становлять операціоналізація показників, кореляційний аналіз, аналіз часових рядів та візуалізація результатів. Емпіричні результати засвідчили наявність сильних позитивних кореляцій між високим рівнем експорту ІКТ-послуг, розвитком ІКТ-інфраструктури, часткою ІКТ-фахівців у структурі зайнятості та часткою ІТ-сектора у ВВП і ВДВ України. Позитивний вплив також виявлено для індикаторів, що характеризують інвестиції в освіту та науку, рівень участі в міжнародній торгівлі, а також кількість наукових досліджень з ІКТ. Водночас визначено низку негативних

чинників, що обмежують конкурентоспроможність та частку ІТ-сектора в економіці України, серед яких: низький рівень фінансування інновацій, регуляторна нестабільність, недостатній розвиток венчурного капіталу, кіберризики, високий рівень міграції ІКТ-фахівців за кордон. Статистична перевірка гіпотез підтвердила значущість виявлених зв'язків між факторами міжнародної конкурентоспроможності ІТ-сектора та ВВП і ВДВ України. Практичне значення дослідження полягає у формуванні аналітичної бази для розробки державної політики з підтримки ІТ-сектора, спрямованої на посилення його ролі в економічному розвитку країни та зміцнення позицій України на світовому ІКТ-ринку.

***Ключові слова**: конкурентоспроможність, ІТ-сектор, ІКТ-інфраструктура, людський капітал, ділове та регуляторне середовище, НДДКР, міжнародні економічні відносини, кореляція.*

***Табл.:** 8. **Формул:** 5. **Бібл.:** 12.*

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In the context of global digital transformation, the information and communication technology (ICT) sector has become a strategic driver of economic development, innovation and international competitiveness. For countries such as Ukraine, the ICT sector not only plays a key role in the development of technological capabilities, but also contributes significantly to national economic indicators, including gross domestic product (GDP) and gross value added (GVA). In recent years, Ukraine's ICT sector has demonstrated resilience and growth potential despite economic and geopolitical challenges, contributing to exports, creating high-skilled jobs and attracting foreign investments. However, there remains a critical gap in understanding how the specific factors affecting ICT sector's international competitiveness are statistically related to its actual contribution to the economy of Ukraine.

The theoretical basis for the system of factors influencing the development and international competitiveness of the ICT sector was formed by studies [1; 2], in which the authors considered factors related to ICT infrastructure, human capital, favourable business environment in the country (political stability, low corruption, effective governance, etc.), FDI, geographical location, corporate culture, etc.

At the same time, studies [3–6] emphasise the growing importance of information technologies in Ukraine as a critical driver of national economic growth, innovation and global competitiveness. In particular, these studies: 1) present forecasts using trend lines and neural networks that indicate further expansion driven by GDP, wages, FDI, and exports [3]; 2) analyse how participation in the global ICT services market affects economic indicators (GDP, CPI, and exchange rates), emphasising that ICT trade has a stronger economic impact in low GDP countries, including Ukraine [4]; 3) offer a comparative global analysis showing how digitalisation, in particular infrastructure and ICT exports, stimulate technology-intensive trade [5]; and 4) focus on the domestic ICT market in Ukraine, confirming the strong correlation between ICT exports, research investment and GDP growth, reinforcing the strategic value of the ICT sector in both national and regional economic development [6].

Finally, conceptually close in approach to our study are the scientific works [7; 8], in which the international competitiveness of the ICT sector is considered, calculated and modelled through five groups of factors: ICT infrastructure, human capital, business and regulatory environment, R&D and the level of international economic integration of the ICT sector.

Despite the growth of the ICT sector in Ukraine and its rapid integration into the global digital economy in recent years, there remains a significant knowledge gap in the quantitative relationships between the factors that influence its international competitiveness and its actual contribution to

Ukraine's national economic indicators, in particular, gross domestic product (GDP) and gross value added (GVA). A systematic empirical study of this issue is relevant because: 1) the results of the correlation analysis can be used by government officials to determine which competitiveness factors are most related to the contribution of the ICT sector to Ukraine's GDP and GVA, thus stimulating more targeted and effective strategies for the development of the ICT sector; 2) understanding how the competitiveness factors of the domestic ICT sector affect the economic performance of Ukraine is important for aligning the domestic ICT sector with the requirements of the global ICT market, which will improve its international positioning; 3) the results of the study can provide a basis for establishing a monitoring system to track the effectiveness of strategies aimed at improving the efficiency of the ICT sector, contributing to long-term economic resilience and sustainable development.

The *aim of the study* is to identify, analyse and quantify the relationships between the key factors of international competitiveness of Ukraine's ICT sector and its economic contribution, measured by its share in GDP and GVA of Ukraine.

The research uses a combination of quantitative, statistical and analytical methods to provide a comprehensive and evidence-based analysis. In particular, the main *research methods* used include: operationalisation (to select, define and quantify the relevant impact of competitiveness factors on the structural indicators of the ICT sector in Ukraine's economy), correlation analysis (to identify and measure the strength and direction of statistical relationships between competitiveness factors and the contribution of the ICT sector to GDP and GVA of Ukraine), time series analysis (to study trends and temporal relationships between variables over a certain period of time), synthesis (to interpret statistical data), and visualisation (to present the results in a tabular format).

In today's digital economy, the ICT sector plays a key role in boosting national productivity, innovation and economic growth. A comprehensive assessment of competitiveness should go beyond qualitative assessments and include quantitative performance indicators that reflect its real economic contribution. Among these are the share of the ICT sector in GDP and GVA, as they are the metrics for understanding its importance in the economy as a whole and for making meaningful international comparisons.

ICT infrastructure includes hardware (mainly physical servers), software, networks, data centres, facilities, and related equipment, which is used to develop, test, operate, monitor, manage, and support ICT services [1; 2; 9]. To further clarify the degree of influence of each factor (k1, k2...k21) from the ICT infrastructure component (CIC1) on the structural indicators of the ICT sector in Ukraine's economy, it is necessary to calculate correlation coefficients based on the data from [8] and *Tbl. 1*.

The calculations were carried out in the environment of the MS Excel spreadsheet processor using the statistical function CORREL [11] with the following Formula (1):

$$\frac{\sum(x-\bar{x})\cdot(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\cdot(y-\bar{y})^2}}. \quad \textbf{(1)}$$

Tbl. 2 displays a matrix of all the calculated correlation coefficients of factors $k_1, k_2 \ldots k_{21}$ of the ICT infrastructure component (CIC1) and tests the statistical significance of their relationship with the structural indicators of the ICT sector in Ukraine's economy ($Y_1 - Y_2$) using Student's t-test [12]. The following hypotheses were tested:

– $\boldsymbol{H_0}$ **(null hypothesis)** – there is no correlation between the indicator CIC1 (ICT infrastructure) and $Y_1 - Y_2$, i. e. $r = 0$.

– $\boldsymbol{H_A}$ **(alternative hypothesis)** – there is a significant correlation between CIC1 (ICT infrastructure) and $Y_1 - Y_2$, i. e. $r \neq 0$.

To further clarify the degree of influence of each factor ($h_1, h_2 \ldots h_{13}$) of the human capital component (CIC2) on certain indicators of the importance of the ICT sector in Ukraine's economy, we have also calculated the correlation coefficients based on the data from [8] and Tbl. 1. Thus, *Tbl. 3* represents a matrix of all the calculated correlation coefficients of factors $h_1, h_2 \ldots h_{13}$ of the human capital component (CIC2) and tests the statistical significance of their correlation with the structural indicators of the ICT sector in Ukraine's economy ($Y_1 - Y_2$) using Student's t-test [12]. We have formulated the following hypotheses:

Table 1

Share of the ICT sector in Ukraine's economy

Indicator/ Year	Notation	2018	2019	2020	2021	2022
% of ICT sector in GPD	Y_1	3,81	3,94	4,21	4,69	4,87
% of ICT sector in GVA	Y_2	4,51	4,65	4,94	5,46	5,55

Source: calculated using [10].

Table 2

Correlation matrix of ICT infrastructure indicators (CIC1) with structural indicators of the ICT sector

Indicator	Notation	Y_1	Y_2	$t(Y_1)$	$t(Y_2)$
Active mobile-broadband subscriptions per 100 inhabitants	k_1	–0,51	–0,46	0,0042	0,0043
Fixed broadband subscriptions (> 10 Mbit/s)	k_2	–0,27	–0,22	0,0001	0,0001
Fixed broadband subscriptions per 100 inhabitants	k_3	–0,52	–0,47	0,0024	0,0029
Households with a computer (%)	k_4	–0,57	–0,56	0,0194	0,0196
Households with Internet access at home (%)	k_5	–0,49	–0,43	0,0009	0,0009
% of Internet users	k_6	–0,56	–0,50	0,0003	0,0003
Total fixed broadband subscriptions	k_9	–0,43	–0,39	$78 \cdot e^{-6}$	$78 \cdot e^{-6}$
Population covered by a mobile-cellular network (%)	k_{10}	0,00	0,00	$1 \cdot e^{-10}$	$1 \cdot e^{-10}$
Population covered by at least a 3G mobile network	k_{11}	0,77	0,78	$1 \cdot e^{-10}$	$1 \cdot e^{-10}$
Population covered by at least a 4G mobile network	k_{12}	0,70	0,71	0,0178	0,0185
Fixed broadband basket as a % of GNI p. c.	k_{13}	–0,39	–0,34	$11 \cdot e^{-5}$	$4 \cdot e^{-5}$
Mobile broadband basket as a % of GNI p. c.	k_{14}	–0,93	–0,94	$1 \cdot e^{-5}$	$2 \cdot e^{-6}$
Mobile cellular basket as a % of GNI p. c.	k_{15}	–0,21	–0,26	$6 \cdot e^{-5}$	$2 \cdot e^{-5}$
Mobile data and voice basket (high consumption) as a % of GNI p. c.	k_{16}	–0,94	–0,96	$2 \cdot e^{-5}$	$1 \cdot e^{-5}$
Mobile data and voice basket (low consumption) as a % of GNI p. c.	k_{17}	–0,21	–0,26	$6 \cdot e^{-5}$	$2 \cdot e^{-5}$
Average cost of broadband Internet access	k_{19}	–0,58	–0,58	0,846	0,624
Mean download speed	k_{20}	0,81	0,78	0,076	0,085
Secured Internet servers	k_{21}	–0,81	–0,77	0,0002	0,0002

Source: calculated using [8; 10].

– H_0 **(null hypothesis):** there is no correlation between CIC2 (human capital) and $Y_1 - Y_2$, i. e. $r = 0$.

– H_A **(alternative hypothesis):** there is a significant correlation between CIC2 (human capital) and $Y_1 - Y_2$, i. e. $r \neq 0$.

For further estimation of the degree of influence of each factor (m_1, m_2 ... m_{17}) from the business and regulatory environment component (CIC3) on individual structural indicators of the ICT sector in Ukraine's economy, we have also calculated the correlation coefficients based on the data from [8] and Tbl. 1. Thus, *Tbl. 4* shows a matrix of all the calculated correlation coefficients of the factors m_1, m_2 ... m_{17} of the business and regulatory environment (CIC3) components with the tested statistical significance of their relationship with the structural indicators of the ICT sector in Ukraine's economy ($Y_1 - Y_2$) using Student' t-test [12]. The following hypotheses have been tested:

– H_0 **(null hypothesis):** there is no correlation between CIC3 (business and regulatory environment) and $Y_1 - Y_2$, i. e. $r = 0$.

– H_A **(alternative hypothesis):** there is a significant correlation between CIC3 (business and regulatory environment) and $Y_1 - Y_2$, i. e. $r \neq 0$.

Furthermore, to clarify the degree of influence of each factor (d_1, d_2 ... d_5) of the innovation potential component (CIC4) on individual indicators of the importance of the ICT sector in Ukraine's economy, we have also calculated correlation coefficients based on data from [8] and Tbl. 1. Hence, *Tbl. 5* shows a matrix of all the calculated correlation coefficients of factors d_1, d_2 ... d_5 of the CIC4 component and establishes their relationship with the structural indicators of Ukraine's ICT sector ($Y_1 - Y_2$). In order to test the statistical significance of the relationship (Tbl. 5) between the CIC4 indicators and the structural indicators of the ICT sector in Ukraine's economy ($Y_1 - Y_2$), we have established the following hypotheses using Student's t-test [12]:

– H_0 **(null hypothesis):** there is no relationship between CIC4 (innovation potential) and $Y_1 - Y_2$, i. e. $r = 0$.

– H_A **(alternative hypothesis):** there is a significant correlation between CIC4 (innovation potential) and *Y1 – Y2*, i. e. $r \neq 0$.

Another essential point of the analysis is establishing the degree of influence of each factor (w_1, w_2 ... w_4) of the Ukrainian ICT sector's involvement in the global ICT market (CIC5) on certain indicators of the

Table 3

Correlation matrix of human capital indicators (CIC2) with structural indicators of the ICT sector

Indicator	Notation	Y_1	Y_2	$t(Y_1)$	$t(Y_2)$
Human Development Index	h_1	–0,81	–0,78	$66 \cdot e^{-6}$	$34 \cdot e^{-6}$
The number of employed highly qualified specialists	h_2	–0,68	–0,63	$3 \cdot e^{-6}$	$3 \cdot e^{-6}$
Adult literacy rate (%)	h_3	0,94	0,94	$1 \cdot e^{-11}$	$1 \cdot e^{-11}$
Human Flight and Brain Drain Index	h_4	–0,95	–0,96	0,003	0,157
Education spending (% of GDP)	h_5	0,84	0,80	0,002	0,064
Education spending (% of government spending)	h_6	–0,69	–0,65	0,001	0,002
PISA results in mathematics	h_7	0,68	0,63	$4 \cdot e^{-9}$	$4 \cdot e^{-9}$
Population with advanced ICT skills (%)	h_8	0,26	0,31	$2 \cdot e^{-6}$	$1 \cdot e^{-6}$
Average salary in the ICT sector (PPP)	h_9	0,62	0,62	0,001	0,001
English Proficiency Index	h_{10}	0,97	0,96	0,046	0,046
Business skills rank	h_{11}	0,60	0,55	0,012	0,013
Technology skills rank	h_{12}	0,61	0,62	0,001	0,001
Data science rank	h_{13}	0,68	0,72	0,001	0,001

Source: calculated using [8; 10].

Table 4

Correlation matrix of business and regulatory environment indicators (CIC3) with structural indicators of the ICT sector

Indicator	Notation	Y_1	Y_2	$t(Y_1)$	$t(Y_2)$
Corruption Perceptions Index	m_1	0,20	0,19	$1 \cdot e^{-7}$	$1 \cdot e^{-7}$
International Property Rights Index	m_2	0,22	0,29	0,942	0,025
Index of Economic Freedom	m_3	0,97	0,97	$1 \cdot e^{-7}$	$1 \cdot e^{-7}$
Regulatory quality index	m_4	–0,83	–0,82	$1 \cdot e^{-7}$	$1 \cdot e^{-7}$
Government effectiveness index	m_5	–0,89	–0,87	$3 \cdot e^{-6}$	$3 \cdot e^{-6}$
Political stability index	m_6	0,15	0,21	0,035	0,057
GovTech Maturity Index	m_7	0,92	0,91	$13 \cdot e^{-6}$	$6 \cdot e^{-6}$
ICT Regulatory Tracker	m_8	0,60	0,61	$1 \cdot e^{-18}$	$1 \cdot e^{-18}$
Global Cybersecurity Index	m_9	–0,85	–0,86	$2 \cdot e^{-10}$	$2 \cdot e^{-10}$
Corporate tax rate	m_{10}	–	–	$3 \cdot e^{-7}$	$4 \cdot e^{-7}$
Social security rate for companies	m_{11}	–0,60	–0,61	$1 \cdot e^{-7}$	$1 \cdot e^{-7}$
Social security rate for employees	m_{12}	–0,60	–0,61	$3 \cdot e^{-5}$	$2 \cdot e^{-5}$
Sales tax rate	m_{13}	0,39	0,44	$2 \cdot e^{-7}$	$2 \cdot e^{-7}$
Inward FDI flows	m_{14}	–0,24	–0,21	0,737	0,433
Inward FDI stocks	m_{15}	0,54	0,59	$1 \cdot e^{-4}$	$1 \cdot e^{-4}$
Inward FDI stocks (% of GDP)	m_{16}	–0,95	–0,95	$1 \cdot e^{-5}$	$1 \cdot e^{-5}$
Inward FDI stocks (% of GFCF)	m_{17}	0,92	0,91	$9 \cdot e^{-5}$	$9 \cdot e^{-5}$

Source: calculated using [8; 10].

importance of the ICT sector in Ukraine's economy. Thus, we have calculated the correlation coefficients based on the data from [8] and Tbl. 1. *Tbl. 6* shows a matrix of all the calculated correlation coefficients of factors w_1, w_2 ... w_4 of the CIC5 component and establishes their relationship with the structural indicators of Ukraine's ICT sector ($Y_1 - Y_2$). In order to test the statistical significance of the relationship (Tbl. 6) between the CIC5 indicators and the structural indicators of the ICT sector in Ukraine's economy ($Y_1 - Y_2$),

Table 5

Correlation matrix of innovation capacity indicators (CIC4) with structural indicators of the ICT sector

Indicator	Notation	Y_1	Y_2	$t(Y_1)$	$t(Y_2)$
Researchers per million inhabitants	d_1	–0,96	–0,95	$3 \cdot e^{-4}$	$3 \cdot e^{-4}$
GERD (% of GDP)	d_2	–0,93	–0,92	$4 \cdot e^{-5}$	$2 \cdot e^{-5}$
High-tech export	d_3	–0,97	–0,95	$1 \cdot e^{-4}$	$1 \cdot e^{-4}$
Number of issued patents in ICT	d_4	–0,72	–0,73	0,2423	0,2516
Number of scientific publications in ICT	d_5	–0,60	–0,55	$2 \cdot e^{-4}$	$2 \cdot e^{-4}$

Source: calculated using [8; 10].

Table 6

Correlation matrix of indicators of ICT sector involvement in the global ICT market (CIC5) with structural indicators of the ICT sector

Indicator	Notation	Y_1	Y_2	$t(Y_1)$	$t(Y_2)$
ICT goods exports	w_1	–0,15	–0,20	$2 \cdot e^{-5}$	$2 \cdot e^{-5}$
ICT services exports	w_2	0,98	0,96	0,00213	0,00213
ICT goods imports	w_3	0,79	0,75	$15 \cdot e^{-5}$	$15 \cdot e^{-5}$
ICT services imports	w_4	–0,73	–0,77	$16 \cdot e^{-5}$	$16 \cdot e^{-5}$

Source: calculated using [8; 10].

using Student's t-test [12], we have formulated the following hypotheses:

– H_0 **(null hypothesis):** there is no correlation between CIC5 (involvement of the ICT sector in the global ICT market) and Y_1, Y_2, i. e. $r = 0$.

– H_A **(alternative hypothesis):** there is a significant correlation between CIC5 (involvement of the ICT sector in the global ICT market) and Y_1, Y_2, i. e. $r \neq 0$.

Based on the results of the correlation analysis of the factors affecting the international competitiveness of Ukraine's ICT sector, we can identify a subgroup of the most significant factors for further research. These factors have been selected based on their potential to influence the key structural indicators of the ICT sector in Ukraine's economy, in particular, the share of the ICT sector in GDP and the share of the ICT sector in GVA. In the process of selecting a subgroup of factors, we were guided by the strength and direction of their correlation with these indicators, providing a targeted approach to understanding their economic impact.

Tbl. 7 highlights the factors that influence the competitiveness of Ukraine's ICT sector and its share in Ukraine's GDP (Y_1), measured by their correlation coefficients, in descending order. Thus, factors related to ICT infrastructure, human capital, and innovation have the greatest positive impact on the share of the ICT sector in GDP (Y_1). Conversely, the most critical negative factors that reduce the share of the ICT sector in GDP are related to structural issues, including dependence on FDI, weak cybersecurity infrastructure, ineffective regulation, and brain drain.

In particular, the potential positive impact of the factors in Tbl. 7 on the share of the ICT sector in Ukraine's GDP (Y_1) can be characterised by the following statements:

1) high export volumes (w_2), economic freedom (m_3) and foreign investment (m_{17}) have the potential to expand infrastructure and opportunities for ICT development, directly increasing the share of the ICT sector in GDP and highlighting the importance of maintaining open and competitive markets;
2) a competent and skilled workforce (h_3) with English proficiency skills (h_{10}), mathematics skills (h_7), technology skills (h_{12}), data processing skills (h_{13}), etc. is the backbone of knowledge- and technology-intensive sectors;
3) promoting investment in education and training (h_5) will ensure a constant supply of talent for the ICT sector in Ukraine;
4) reliable, broad, and high-quality Internet access (k_{11}, k_{12}, k_{20}) and effective digital governance (m_7) promote digital inclusion and expand domestic ICT consumption, and create a system suitable for development, innovation, efficiency, and scaling for ICT businesses;

Table 7

Factors influencing the share of the ICT sector in Ukraine's GDP (Y_1)

Degree of relationship	Positive impact on GDP (Y_1)	Negative impact on GDP (Y_1)
Very strong relationship (1 – 0,8)	ICT goods exports, Index of Economic Freedom, English Proficiency Index, adult literacy rate (%), Inward FDI stocks (% of GFCF), GovTech Maturity Index, education spending (% of GDP), mean download speed	Secured Internet servers, Human Development Index Regulatory quality index, Global Cybersecurity Index, Government effectiveness index, mobile broadband basket, GERD (% of GDP), mobile data and voice basket (high consumption), Inward FDI stocks (% of GDP), Human Flight and Brain Drain Index, researchers per million inhabitants, high-tech export
Strong relationship (0,8 – 0,6)	ICT goods imports, population covered by at least a 3G mobile network, population covered by at least a 4G mobile network, PISA results in mathematics, data science skills rank, average salary in the ICT sector, technology skills rank, ICT Regulatory Tracker	Social security rate for companies, social security rate for employees, number of scientific publications in ICT, the number of employed highly qualified professionals, education spending (% of government spending), number of issued patents in ICT, ICT services imports

Source: compiled according to Tbl. 2 – Tbl. 6.

5) a stable ICT regulatory framework (m_8) and competitive wages (h_9) attract and motivate qualified ICT talent, increasing the international investment attractiveness of the ICT sector;
6) balanced ICT imports (w_3) provide access to global technologies while promoting the prosperity of domestic ICT services.

In summary, the direct positive impact of the selected factors on the change in the share of the ICT sector in Ukraine's GDP (ΔY_1) can be represented in the form of Formula (2):

$$\Delta Y_1 = 0{,}976 \times w_2 + 0{,}969 \times m_3 + 0{,}967 \times h_{10} + \\ + 0{,}939 \times h_3 + 0{,}919 \times m_{17} + 0{,}916 \times m_7 + 0{,}837 \times \\ \times h_5 + 0{,}812 \times k_{20} + 0{,}767 \times w_3 + 0{,}765 \times k_{11} + \\ + 0{,}699 \times k_{12} + 0{,}683 \times h_7 + 0{,}681 \times h_{13} + 0{,}625 \times \\ \times h_9 + 0{,}611 \times h_{12} + 0{,}601 \times m_8. \quad (2)$$

At the same time, the potential negative impact of the factors in Tbl. 7 on the share of the ICT sector in Ukraine's GDP (Y_1) can be characterised by the following statements:

1) reducing connection costs to intensify ICT adoption and stimulate domestic market growth (k_{14}, k_{16}), as well as increasing the number of secure servers to enhance trust in digital transactions and ICT services (k_{21}) can significantly improve access to and confidence in ICTs, thus contributing to the growth of the ICT sector's role in Ukraine's economy;
2) an inadequate regulatory environment (m_4) and inefficient public administration (m_5) hinder innovation and growth of the ICT sector; besides, weak cybersecurity standards (m9) expose vulnerabilities in the ICT infrastructure, discourage investment and reduce the international competitiveness of Ukraine's ICT sector;
3) limited public investment in education (h_6) hinders the development of a skilled workforce (h_2), and insufficient human development (h_1) and migration of ICT talent (h_4) deplete the competent talent pool of the ICT sector;
4) insufficient investment in R&D (d_2) leads to a decrease in the number of scientists (d_1), reducing scientific research (d_5), intellectual property in ICTs (d_3), and presence in foreign markets of high-tech products (d_4);
5) excessive dependence on ICT imports (w_4) limits the formation of domestic value added, negatively affecting the contribution of the ICT sector to Ukraine's GDP;
6) simplification of social insurance ($m11$) and labour taxation (m_{12}) policies can make the ICT sector more attractive to employers and professionals;
7) low level of foreign investment reduces the capital (m_{16}) available for the development of the ICT sector.

The direct negative impact of the selected factors on the change in the share of the ICT sector in Ukraine's GDP (ΔY1) can be represented in the form of Formula (3):

$$\Delta Y_1 = -0{,}81 \times k_{21} - 0{,}81 \times h_1 - 0{,}833 \times m4 - 0{,}849 \times \\ \times m_9 - 0{,}888 \times m_5 - 0{,}927 \times k_{14} - 0{,}929 \times d_2 - 0{,}944 \times \\ \times k_{16} - 0{,}952 \times m_{16} - 0{,}954 \times h_4 - 0{,}965 \times d_1 - 0{,}969 \times \\ \times d_4 - 0{,}601 \times m_{11} - 0{,}601 \times m_{12} - 0{,}604 \times d_5 - 0{,}684 \times \\ \times h_2 - 0{,}69 \times h_6 - 0{,}724 \times d_3 - 0{,}727 \times w_4. \quad (3)$$

Table 8

Factors influencing the share of the ICT sector in Ukraine's GVA (Y_2)

Degree of relationship	Positive impact on GVA (Y_2)	Negative impact on GVA (Y_2)
Very strong relationship (1 – 0,8)	Index of Economic Freedom, ICT services exports, English Proficiency Index, adult literacy rate (%), Inward FDI stocks (% of GFCF), GovTech Maturity Index, education spending (% of GDP)	Education spending (% of government spending), Regulatory quality index, Global Cybersecurity Index, Government effectiveness index, GERD (% of GDP), mobile broadband basket, Inward FDI stocks (% of GDP), high-tech export, researchers per million inhabitants, Human Flight and Brain Drain Index, mobile data and voice basket (high consumption)
Strong relationship (0,8 – 0,6)	Mean download speed, population covered by at least a 3G mobile network, ICT goods imports, data science skills rank, population covered by at least a 4G mobile network, PISA results in mathematics, average salary in the ICT sector, technology skills rank, ICT Regulatory Tracker	Number of scientific publications in ICT, social security rate for companies, social security rate for employees, the number of employed highly qualified professionals, number of issued patents in ICT, secured Internet servers, ICT services imports, Human Development Index

Source: compiled according to Tbl. 2 – Tbl. 6.

Tbl. 8 displays the factors that influence the international competitiveness of Ukraine's ICT sector and their impact on its share in Ukraine's gross value added (Y_2), measured by their correlation coefficients.

Specifically, the potential positive impact of the factors in Tbl. 8 on the share of the ICT sector in Ukraine's GVA (Y_2) can be characterised by the following statements:

1) a high level of economic freedom (m_3) contributes to the creation of a favourable macroeconomic environment for entrepreneurship, innovation and investment (m_{17}) in ICT infrastructure, R&D and talent development for the ICT sector, directly increasing its contribution to GVA;
2) high exports of ICT services (w_2) demonstrate strong global demand, increasing foreign exchange earnings and value added by the ICT sector;
3) promoting investment in education (h_5) will provide the required number of qualified ICT professionals with high literacy (h_3), English language skills (h_{10}), good skills in mathematics, technology and Data Science (h_7, h_{12}, h_{13}), while competitive salaries (h_9) will help retain the ICT sector's talent pool in Ukraine to further develop innovation;
4) investments in ICT infrastructure (k_{11}, k_{12}) will provide wider and faster access (k_{20}) of users to ICT services and products, which will increase economic activity and productivity;
5) the maturity of the e-government system (m_7) and the ICT regulatory framework (m_8) support the development of the industry by ensuring stability, transparency and opportunities for scaling up digital businesses.

In summary, the direct positive impact of the selected factors on the change in the share of the ICT sector in Ukraine's GVA (ΔY_2) can be represented in the form of Formula (4):

$$\Delta Y_2 = 0{,}968 \times m_3 + 0{,}961 \times w_2 + 0{,}959 \times h_{10} + 0{,}94 \times h_3 + 0{,}915 \times m_{17} + 0{,}914 \times m_7 + 0{,}801 \times h_5 + 0{,}78 \times k_{20} + 0{,}775 \times k_{11} + 0{,}747 \times w_3 + 0{,}717 \times h_{13} + 0{,}708 \times k_{12} + 0{,}632 \times h_7 + 0{,}621 \times h_9 + + 0{,}619 \times h_{12} + 0{,}61 \times m_8. \quad (4)$$

Yet, the potential negative impact of the factors in Tbl. 8 on the share of the ICT sector in Ukraine's GVA (Y_2) can be characterised by the following statements:

1) a weak regulatory framework (m_4), inefficient public administration (m_5), and inadequate cybersecurity infrastructure (m_9) hinder the development of ICTs, reducing the confidence of domestic and foreign users and investors and slowing down the growth of the ICT sector;
2) the low R&D intensity in Ukraine's GDP (d_2), the declining number of researchers (d_1) and the high brain drain (h_4) lead to limited results in R&D and innovation in Ukraine's economy, thereby limiting the ICT sector's ability to generate greater added value;
3) limited scientific research in ICTs (d_5) and low number of registered patents in ICTs (d_3) indicate a lack of innovation, which limits the

development of new high value-added ICT products and services;

4) the low share of high-tech exports (d_4) indicates limited competitiveness in global markets, which hinders the growth of the ICT sector's share in Ukraine's GVA;
5) high prices for Internet connection (k_{14}, k_{16}) reduce accessibility for enterprises and consumers, which limits the growth of the ICT sector's share in GVA of Ukraine's economy;
6) the high tax burden (m_{11}, m_{12}) prevents ICT companies from scaling up their economic activities, hindering growth and job creation in the ICT sector;
7) low indicators of human development (h_1) and education expenditures (h_6) affect the availability of qualified ICT professionals (h_2), impeding the long-term growth of the ICT sector's share in Ukraine's GVA;
8) insufficient number of secure servers (k_{21}) undermines trust in the digital environment of the ICT sector, thus reducing the consumption of ICT services and the impact of the ICT sector on GVA of Ukraine's economy;
9) inefficient use of FDI in the ICT sector (m_{16}) limits the potential for growth in innovation and productivity of the ICT sector.

In summary, the direct negative impact of the selected factors on the change in the share of ICTs in Ukraine's GVA (ΔY_2) can be represented in the form of Formula (5):

$$\Delta Y_2 = -0{,}649 \times h_6 - 0{,}815 \times m_4 - 0{,}864 \times m_9 - 0{,}867 \times m_5 - 0{,}92 \times d_2 - 0{,}938 \times k_{14} - 0{,}948 \times m_{16} - 0{,}950 \times d_4 - 0{,}950 \times d_1 - 0{,}958 \times h_4 - 0{,}961 \times k_{16} - 0{,}554 \times d_5 - 0{,}609 \times m_{11} - 0{,}61 \times m_{12} - 0{,}633 \times h_2 - 0{,}733 \times d_3 - 0{,}769 \times k_{21} - 0{,}769 \times w_4 - 0{,}781 \times h_1. \quad (5)$$

CONCLUSIONS

Based on the correlation analysis, a number of key factors have been identified that have the greatest impact on the international competitiveness of Ukraine's ICT sector, in particular, its share in the country's gross domestic product (GDP) and gross value added (GVA). Statistical testing of the hypotheses using the Student's t-test confirmed the significance of the established relationships, which allows us to reasonably reject the null hypotheses ($r = 0$) and accept the alternative ones ($r \neq 0$). The results of the analysis enabled us to form a subgroup of variables for further research, taking into account both the strength and direction of their correlation with the target economic indicators. Positive factors include high levels of ICT services exports, economic freedom, investment in education, availability of a highly skilled and digitally literate workforce, as well as access to quality ICT infrastructure. However, structural deficiencies in the regulatory environment, weak cybersecurity, insufficient R&D funding, migration of ICT talent, and over-reliance on imported ICT goods have a negative impact. Promising areas for future research include: building econometric models with time series (to track the long-term impact of individual factors), assessing institutional differences that cause different impacts of the same factors on the ICT sectors of different countries, studying synergies between factors, and scenario modelling for sustainable development of Ukraine's ICT sector under different conditions. ■

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