

ICT SECTOR COMPETITIVENESS: A COMPARATIVE ANALYSIS OF UKRAINE AND OTHER 7 EASTERN EUROPEAN COUNTRIES

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Abstract.

Ukraine's ICT sector remains one of the most promising industries in the country, as it continues to grow and develop despite difficult economic and political conditions. Through comparative analysis, this paper evaluates Ukraine's ICT sector performance and competitiveness within the region. The conducted research confirms the proper development of the ICT infrastructure, human capital and ICT services export by Ukraine's ICT sector. However, there has been a decline in Ukraine's scientific and research activities, in particular, a reduction in the number of scientists and ICT patents issued, a decline in GERD as a % of GDP and the volume of high-tech exports. We noted that the main competitive disadvantage of Ukraine's ICT sector is opaque and ineffective domestic legislation on the protection of property rights, combating corruption, ensuring economic freedoms, etc., which in turn prevents the ICT sector of Ukraine from strengthening its own competitive advantages and reduces its investment attractiveness. Finally, we emphasized the need for a multilateral approach to restructuring Ukraine's ICT sector, taking into account domestic legislation update, strengthening security measures to protect the ICT infrastructure, and further development of highly qualified human capital for the ICT sector.

Key words: ICT sector; competitiveness; competitive advantages; ICT services.

1. Introduction

The Information and Communication Technology (ICT) sector is a global economic growth engine, particularly in Eastern Europe, where significant transformations have occurred (Latysheva et al., 2020). Zavhorodnya and Melnyk (2023) admit that competition in ICT sector involves innovation, resource management, pricing strategies, quality of digital goods, as well as adaptation to changing market conditions, meeting consumer needs, development of advanced technologies, and customers loyalty retention. Moreover, ICT sector faces significant competition due to innovation intensity, short product life cycles, intellectual property protection, strategic partnerships, constant M&A agreements, fierce price competition, high demand for AI and ML specialists, and significant reliance on privacy, data security, and competition legislation.

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In addition, the authors highlighted the main features of ICT sector competitiveness for stakeholders: (1) consumers (obtaining a wide range of technological solutions, access to information, etc.), (2) IT companies (access to highly qualified human capital, developed digital infrastructure, protection objects of intellectual property, etc.), (3) investors (high return on investment, promising areas of research and development, etc.), (4) IT specialists (fair salaries, opportunities for professional development, etc.) and (5) states (increasing social and economic welfare, security, etc.).

Kudyrko and Shevchenko (2023) discuss the significance of the Ukraine's ICT sector formation and development as a crucial element of the country's strategy to enhance national economic competitiveness in the face of global challenges. Particularly, the authors proved that successful development of ICT sector requires specific organizational and institutional conditions, considering factors like economic development, scientific and technical potential, regulatory environment, highly qualified personnel, financing, favorable ecosystem, as well as cooperation between business, government, and research institutions.

Hence, the purpose of this study is to examine the complex landscape of Ukraine's ICT sector: firstly, to provide a comprehensive analysis of the current state and dynamics of the sector within Ukraine, and secondly, to contextualize our findings by drawing comparisons with neighboring Eastern European countries. Through this approach, we seek to illuminate the distinctive strengths, challenges, and opportunities that Ukraine's ICT sector presents in the broader regional context. By analyzing the economic and political context, talent pool, market dynamics, policy and regulation, investment opportunities, and collaboration potential, this study provides valuable insights into the region's ICT industry. Additionally, this research aims to contribute to a deeper understanding of the factors driving growth and innovation in Ukraine's ICT sector, as well as the barriers that may impede its further development. Finally, comparing countries' regulatory frameworks and policies can provide insights into their impact on the sector.

2. Research Methodology

The present study aims to attain its objectives by utilizing the composite index method for measuring Ukraine's ICT sector international competitiveness, as proposed by Melnyk & Zavhorodnya (2023). Specifically, ICT sector international competitiveness Index (ITSIC) incorporates 35 indicators that are categorized into five sub-indices, as denoted by formula 1.

$$, \quad (1)$$

where ICTI – ICT Infrastructure Sub-Index; HCI – Human Capital Sub-Index; BREI – Business and Regulatory Environment Sub-Index; RDI – R&D Potential Sub-Index; ITII – ICT Sector Involvement Sub-Index.

Table 1 displays the allocation of 35 indicators to the designated sub-indices. The present method employs open statistical databases of international governmental and non-governmental organizations, including but not limited to UNCTAD, World Intellectual Property Organization, World Bank, International Telecommunication Union, UNESCO, International Labor Organization, UNDP, Transparency International, and The Heritage Foundation, to derive the source base for calculating the ITSIC index.

Table 1. ICT Sector International Competitiveness Index (ITSIC) Structutre

Sub-Index Title	Number of Indicators	Included Indicators
ICTI	9	Population covered by a mobile-cellular network (%),Households with Internet access at home (%),Individuals using the Internet (%), Fixed broadband subscriptions per 100 inhabitants, Price of broadband (USD per month), Mobile data price (USD per 1 GB), Mean download speed (Mbps), International bandwidth per Internet user (kbit/s), Secure Internet servers (per 1 mln. people)
HCI	6	Human Development Index, Literacy rate (% of people ages 15 and above), The number of employed highly qualified specialists, Population with advanced ICT skills (%),English Proficiency Index
BREI	9	Corruption Perceptions Index, International Property Rights Index, Index of Economic Freedom, Regulatory quality index, Government effectiveness index, Political stability index, GovTech Maturity Index (GTMI), ICT Regulatory Tracker, Global Cybersecurity Index
RDI	5	Researchers per million inhabitants, GERD as a percentage of GDP, The number of issued patents in ICT, High-tech export, Scientific works in ICT
ITII	6	ICT goods export and import (mln. USD), ICT services export and import (mln. USD), WTO and OECD membership

Formula 2 outlines the calculation methodology for ICTI, HCI, BREI, RDI, and ITII sub-indices.

$$- , \tag{2}$$

where j – indicator category; i_{norm} –normalized index of the j -category; n – the number of j -category indicators.

Normalization of indicators, where the maximum recorded value is considered the standard, is carried out according to the formula 3.

(3)

The normalization of indicators, where the minimum recorded value is considered the standard, is carried out according to the formula 4.

(4)

The proposed methodology for evaluating ICT sector international competitiveness sector offers several distinct advantages. It encompasses a multitude of determinants and indicators, affording a comprehensive perspective on IT sector development and facilitating exhaustive analysis. Furthermore, it furnishes a standardized and unified metric, streamlining comparative assessments across diverse IT sectors or geographical regions. This approach additionally serves to pinpoint the strengths and weaknesses inherent in the IT sector, thereby enabling the formulation of efficacious strategies and policies. Moreover, it presents the opportunity for sustained, long-term monitoring of IT sector competitiveness and the discernment of emergent trends and transformations. Lastly, the utilization of official international databases extends the purview of research into IT sector competitiveness, encompassing both regional and global levels of analysis.

3. Ukraine's Digital Landscape in Eastern Europe: ITSIC Index Perspective

Ukraine's journey to building a robust ICT infrastructure can be traced back to the early 1990s after the dissolution of the Soviet Union. During this period, Ukraine embarked on the path of economic reform and transition to a market economy, what created opportunities for the development of Ukraine's ICT sector (Tsaras et al., 2018).

Ukraine's internet connectivity has grown significantly, with high-speed internet now available in urban and rural areas progressively becoming linked through government programs (Semenets-Orlova et al., 2022). Additionally, Ukraine's well-developed telecommunications network allows for cross-country communication and data transfer. In particular, according to ITU data (2023), about 99.9% of Ukraine's population was covered by a mobile-cellular network in 2021. Moreover, significant growth was observed in the share of Ukraine's population covered by at least a 3G mobile network: from 1.4% in 2010 to 91.6% in 2021 (with the transition to 4G network coverage). Similarly, fixed broadband subscriptions rose from 2.956 mln. in 2010 to 7.56 mln. in 2021 (156% growth), as well as share of households with with Internet access increased from 22,2% to 82.7% and share of Internet users increased from 23.3% to 79.2%.

Despite the results of ICTI (Table 2), Ukraine is at the same level as the key exporters of Eastern Europe in terms of most indicators of ICT infrastructure development (e.g. Internet coverage of the population), however, significantly inferior in terms of mean download speed (25.3 Mbps). However, Ukraine is the absolute leader among the analyzed countries in terms of the average cost of broadband Internet access (6.4 USD per month).

Table 2. ICT Infrastructure Sub-Index Scores in Eastern Europe

Country / Year	2019		2020		2021	
	ICTI score	Ran k	ICTI score	Ran k	ICTI score	Ran k
<i>Ukraine</i>	0,387	7	0,454	6	0,460	6
<i>Romania</i>	0,644	1	0,620	2	0,586	3
<i>Poland</i>	0,618	4	0,578	4	0,570	4
<i>Czech Republic</i>	0,569	5	0,476	5	0,397	8
<i>Hungary</i>	0,497	6	0,444	7	0,632	2
<i>Moldova</i>	0,357	8	0,367	8	0,431	7
<i>Slovak Republic</i>	0,642	2	0,601	3	0,522	5
<i>Bulgaria</i>	0,640	3	0,672	1	0,658	1

Source: Developed by authors based on (ITU, 2023; The World Bank, 2023; Cable.co.uk, 2023)

The IT talent pool in Ukraine is distinguished by its exceptional quality, which can be attributed to a combination of factors such as high-quality formal and informal education, strong motivation, and ample opportunities for professional development among IT specialists. These opportunities include internships, educational and training activities facilitated by IT clusters, state-sponsored programs, and other similar initiatives. According to the ITU (2023), in 2021 Ukraine ranked second among the key ICT exporters of Eastern Europe in terms of users with advanced ICT skills number (529.7 thousand users), second only to Poland (1.89 million users). Furthermore, Ukraine's ICT sector is replenished with new ICT professionals the fastest among all analyzed countries: approximately 27 thousand students of technical specialties graduate from universities every year (compared to 25 thousand students in Poland, 8.2 thousand in Romania and 4.6 thousand in Czech Republic) (N-iX, 2023). Most of the technical talents have an intermediate level of English and above, which is also a competitive advantage, as it greatly simplifies communication with foreign customers (Mironova et al., 2022).

It should be noted that the recruitment of IT professionals from Eastern European nations presents a more advantageous option for companies located in the USA, UK, and Western Europe, as it reduces the annual costs of paying IT developers by an average of 20%. According to the results of a comparative analysis (Plane, 2023), Ukraine ranks second among the countries of Eastern Europe in terms of the cost of hiring software developers (48.2 thousand, USD per year), second only to Moldova (46.3 thousand, USD per year). Additionally, Ukraine ranks sixth within analyzed countries based on Human Resources Sub-Index in 2021 (Table 3).

Table 3. Human Resources Sub-Index Scores in Eastern Europe

Country / Year	2019		2020		2021	
	HRI score	Rank	HRI score	Rank	HRI score	Rank
<i>Ukraine</i>	0,350	6	0,345	6	0,360	6
<i>Romania</i>	0,422	4	0,444	4	0,466	4
<i>Poland</i>	0,704	1	0,691	1	0,764	1
<i>Czech Republic</i>	0,610	2	0,644	2	0,577	2
<i>Hungary</i>	0,546	3	0,505	3	0,541	3
<i>Moldova</i>	0,138	8	0,136	8	0,174	8
<i>Slovak Republic</i>	0,416	5	0,394	5	0,396	5
<i>Bulgaria</i>	0,268	7	0,198	7	0,232	7

Source: Developed by authors based on (UNDP, 2021; ILO, 2021; The World Bank, 2023; ITU, 2023)

The competitiveness and investment attractiveness of ICT sector are subject to substantial influence from the business and regulatory environment within which it operates (Kalina et al., 2022). This environment characterized by stability, transparency in regulations, streamlined bureaucratic processes, and robust legal safeguards has the potential to foster investment inflows and propel growth in the ICT sector. Conversely, a challenging environment marked by uncertainty, opacity in regulations, bureaucratic inefficiencies, and inadequate legal protections can act as deterrents to potential investors and impede the development and progress of the ICT sector. The study shows certain competitive disadvantages for Ukraine's ICT sector, given it eighth rank within analyzed countries based on Business and Regulatory Environment Sub-Index in 2021 (Table 4).

Table 4. Business and Regulatory Environment Sub-Index Scores in Eastern Europe

Country / Year	2019		2020		2021	
	BREI score	Rank	BREI score	Rank	BREI score	Rank
<i>Ukraine</i>	0,066	8	0,018	8	0,096	8
<i>Romania</i>	0,523	6	0,620	5	0,502	6
<i>Poland</i>	0,800	2	0,852	2	0,701	3
<i>Czech Republic</i>	0,820	1	0,957	1	0,866	1
<i>Hungary</i>	0,742	3	0,810	4	0,750	2
<i>Moldova</i>	0,258	7	0,218	6	0,382	7
<i>Slovak Republic</i>	0,730	4	0,837	3	0,688	4
<i>Bulgaria</i>	0,643	5	0,584	7	0,513	5

Source: Developed by authors based on (The World Bank, 2023; The Heritage Foundation, 2023; EF EPI, 2021; Property Rights Alliance, 2022; ITU, 2023; Transparency International, 2022)

Analysis of the available data presents a mixed picture of Ukraine's advancements in combating corruption (CPI score – 32), protecting property rights (IPRI score – 4.453), promoting economic freedom (IEF score – 56), and enhancing regulatory quality (improved from -0.59 to -0.28). Although certain areas have observed notable improvements, aspects related to governance and economic stability have posed persistent challenges. The implementation of the GovTech Maturity Index (0.768) and the substantial enhancement in cybersecurity practices (GCI score – 65.93) exemplify Ukraine's commitment to embracing the process of digital transformation. Finally, to ensure enduring growth and competitiveness, it is imperative for Ukraine to maintain momentum by undertaking ongoing reforms in governance and fostering an environment conducive to business operations.

R&D is not only essential for the creation of frontier technologies but also for their adoption and adaptation, as these technologies often necessitate customization or modification for local use (UNCTAD, 2021). Noteworthy, Ukraine's ICT sector innovative potential comprises 544 tech service companies, 1629 tech product companies, 10 business accelerators, 87 R&D centers and 22 IT clusters (Ukraine Tech Ecosystem, 2023).

The study shows (Table 5), that Ukraine's ICT sector has continuous competitive disadvantage in R&D as well as innovative potential. Particularly, in 2014, GERD as a % of GDP in Ukraine was 0.65%, while in 2021 it was 0.29%. Moreover, a downward trend is observed in the number of researchers in Ukraine: 1,024 scientists per 1 million population in 2014, while in 2021 – 587 (a decrease of 42.6%). The analysis showed decrease in innovative activity in ICT: in 2014, 312 patents were issued in Ukraine, while in 2021 – 5 (a decrease of 98.4%). We note that such trends are influenced by an insufficient legal framework for the protection of intellectual property rights, which results in the registration of domestic companies and intellectual property rights abroad. Additionally, there was a 35.5% decline in high-tech exports (from 1.9 billion USD in 2014 to 1.2 billion USD in 2021). However, a positive trend was observed in the number of published scientific works in computer sciences: 1060 articles in 2014 to 4721 articles in 2021 (Scimago, 2023).

Table 5. R&D Potential Sub-Index Scores in Eastern Europe

Country / Year	2019		2020		2021	
	RDI score	Rank	RDI score	Rank	RDI score	Rank
<i>Ukraine</i>	0,212	6	0,143	7	0,123	7
<i>Romania</i>	0,178	7	0,233	6	0,193	6
<i>Poland</i>	0,780	1	0,773	1	0,790	1
<i>Czech Republic</i>	0,728	2	0,731	2	0,698	2
<i>Hungary</i>	0,511	3	0,492	3	0,496	3
<i>Moldova</i>	0,000	8	0,004	8	0,011	8
<i>Slovak Republic</i>	0,315	4	0,337	4	0,298	4
<i>Bulgaria</i>	0,240	5	0,306	5	0,248	5

Source: Developed by authors based on (UNESCO, 2023; WIPO, 2023; The World Bank, 2023; Scimago, 2023)

In recent years, the Ukrainian ICT sector has developed and grown strongly. It should be noted that the export of Ukraine's ICT sector is one of the few among the countries of Eastern Europe, which continued to grow steadily, on average by 17.4% annually. As for 2021, the dominant position in the export of Ukraine's ICT sector remains ICT services with a share of 94% in the total ICT export. In general, the domestic ICT sector took a huge step forward and became an integral part of the Ukrainian economy, forming more than 4% of GDP. Simultaneously, the study shows mixed competitive position of Ukraine's ICT sector, given it fifth rank within analyzed countries based on ICT Sector Involvement Sub-Index in 2021 (Table 6).

Table 6. ICT Sector Involvement Sub-Index Scores in Eastern Europe

Country / Year	2019		2020		2021	
	ITII score	Rank	ITII score	Rank	ITII score	Rank
<i>Ukraine</i>	0,542	5	0,557	5	0,565	5
<i>Romania</i>	0,502	7	0,513	6	0,506	7
<i>Poland</i>	0,642	4	0,631	4	0,623	4
<i>Czech Republic</i>	0,671	1	0,678	1	0,673	1
<i>Hungary</i>	0,644	3	0,651	3	0,649	3
<i>Moldova</i>	0,500	8	0,500	8	0,500	8
<i>Slovak Republic</i>	0,657	2	0,663	2	0,659	2
<i>Bulgaria</i>	0,512	6	0,512	7	0,515	6

Source: Developed by authors based on (UNCTADstat, 2023)

Crucial to mention, that in 2021 the leading ICT exporters in Eastern Europe were: Czech Republic (40.9 bln. USD), Poland (32,5 bln. USD), Hungary (20.2 bln. USD) and Slovak Republic (bln. USD). Moreover, OECD membership creates competitive advantages for ICT sectors of Czech Republic, Poland, Hungary and Slovak Republic. Firstly, these countries have a wider customer base, attracting investments and fostering innovation. Secondly, they also have a skilled workforce, promote technical education and foster a talent pool. Finally, their stable political and economic environments, supported by transparent regulations and strong legal systems, facilitate smooth business operations and foster innovation.

In accordance with the above, ITSIC index results show Ukraine's low ability to compete with other Eastern European countries for foreign customers and partners, as it ranks seventh in Eastern Europe during 2019-2021 (Table 7).

Table 7. ICT Sector International Competitiveness Index Scores in Eastern Europe

Country / Year	2019		2020		2021	
	ITSIC score	Rank	ITSIC score	Rank	ITSIC score	Rank
<i>Ukraine</i>	31,12	7	30,33	7	32,08	7
<i>Romania</i>	45,41	6	48,61	5	45,05	5
<i>Poland</i>	70,88	1	70,51	1	68,95	1
<i>Czech Republic</i>	67,94	2	69,73	2	64,23	2
<i>Hungary</i>	58,80	3	58,03	3	61,36	3
<i>Moldova</i>	25,06	8	24,52	8	29,94	8
<i>Slovak Republic</i>	55,20	4	56,67	4	51,25	4
<i>Bulgaria</i>	46,06	5	45,45	6	43,34	6

Source: Developed by authors

Finally, in 2021 ITI Sub-Index has the most points in the overall assessment of Ukraine’s ICT sector competitiveness in Eastern Europe – 11.3 points out of 20 possible points (35.2% of the obtained value), ICTI Sub-Index – 9.2 points (28.7%) and HR Sub-Index – 7.2 points (22.5%). Meanwhile, the lowest values are R&D Sub-Index – 2.5 points (7.7%) and BRE Sub-Index – 1.9 points (6%).

4. Ukraine's ICT Sector Opportunities and Challenges in the Post-War Era

Following the full-scale invasion of the Russian Federation into Ukraine on February 24th, 2022, the entirety of the nation's economic sectors were compelled to reactively adjust to the altered circumstances of conducting commercial activities. The ICT sector in Ukraine, like many other sectors, faces significant challenges during times of war (Fig. 1).

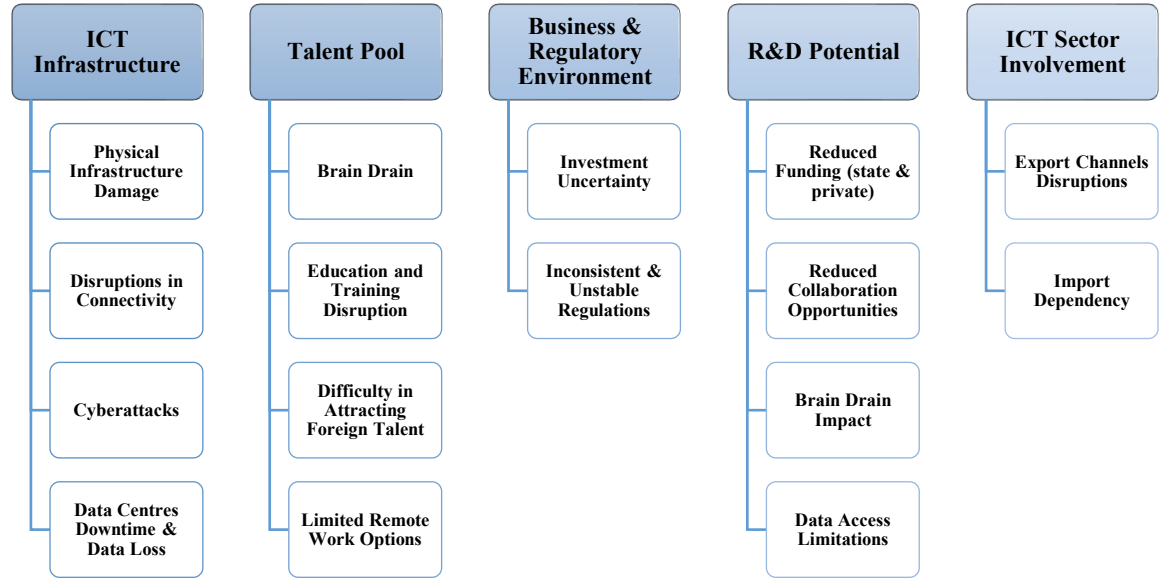


Figure 1. General Challenges Hindering Ukraine's ICT Competitiveness

The ongoing war in Ukraine presents a potential risk of infrastructure disruptions, which may include physical damage, power outages, disruptions in internet connectivity, cyberattacks, and data center failures. This led to an increase in cybersecurity threats, thus requiring IT companies to invest in robust cybersecurity measures to safeguard their data and systems.

Generally, IT companies in Ukraine faced the following challenges related to the war: ban on IT professionals going abroad, migration of employees and their families, IT professionals conscription, insufficient currency regulation and tax legislation, challenges in working with clients, challenges related to relocation, active hostilities, occupation of territories. Additionally, in order to reduce the negative impact of massive missile attacks on Ukraine’s critical and energy infrastructure, IT companies took the following measures: purchased generators, used Starlink, purchased fuel and power banks, created information systems/separate channel for inquiries, paid for relocation to safer regions and co-working spaces, diversified Internet providers, transferred corporate

data to the cloud platforms, equipped offices with the possibility of team accommodation.

According to Microsoft report (Microsoft, 2022), more than 40% of destructive attacks from the Russian Federation were aimed at organizations in the critical infrastructure sectors of Ukraine, which could have a second-order negative impact on the government, army, economy and people; 32% affected Ukrainian governmental organizations at the national, regional and city levels (in particular the report provides examples of cyber attacks preceding air and missile strikes).

In order to address ICT infrastructure challenges related to the war, Ukraine should establish dedicated security teams to protect critical ICT infrastructure, develop a comprehensive redundancy plan, establish emergency communication networks for essential services, and collaborate with private telecom providers to ensure continuity of critical communication services. Additionally, deploying mobile satellite communication vehicles can provide connectivity in crisis-stricken regions, as well as investing in backup power generators and satellite communication links may help to maintain connectivity.

During the post-war period in order to strengthen ICT infrastructure Ukraine should: (1) allocate funds for infrastructure rehabilitation and reconstruction, (2) seek international assistance for rebuilding, (3) prioritize broadband expansion in rural and underserved areas, (4) encourage private sector investment in ICT infrastructure through incentives, tax breaks, or subsidies, and (4) establish ICT innovation hubs and technology parks to promote entrepreneurship and innovation.

Furthermore, for the purpose of developing Ukraine's ICT sector competitiveness, it is important for the government to (1) simplify regulatory procedures to attract FDIs and reduce bureaucratic hurdles, (2) strengthen intellectual property laws and set up specialized intellectual property courts to resolve disputes quickly, (3) to develop adequate data protection and privacy laws in accordance with international standards to increase trust in ICT services, (4) create a regulatory framework to support technology startups (e.g. streamlining company registration and tax regulations, etc.), (5) work with the private sector to develop and update regulations to meet industry needs.

The safety concerns and economic instability faced by Ukraine have resulted in a talent drain, leading to a dearth of qualified IT workers. The ongoing wartime recruitment challenges have made it difficult for potential candidates to join or remain with IT companies, owing to the prevailing uncertainty and security risks. The main reasons for talent drain in Ukraine include safety and security concerns, economic instability, lack of job opportunities, and emigration opportunities (Fig. 2).

The primary obstacle faced by IT professionals amidst the conflict pertained to their geographic mobility. A considerable 64% of these specialists found themselves compelled to relocate due to the wartime conditions; notably, 24% among them have subsequently reestablished residence in their pre-invasion locales (IT Ukraine Association, 2022). Consequently, there has been a notable transformation in the work dynamics, with the onset of full-scale hostilities prompting a shift in work arrangements (transition to remote work). Commonly, IT companies relocated to such countries as Poland (40.1%), Germany (14.6%), the USA and Portugal (9.5%), Bulgaria, the Czech Republic and Romania (8%), Moldova, Spain and Canada (5.1%). Additionally, more actively than before, specialists of the middle level went abroad in 2022 (24% against

14% before), while the share of juniors and interns has also increased, but remains low: 8% compared to 4% earlier

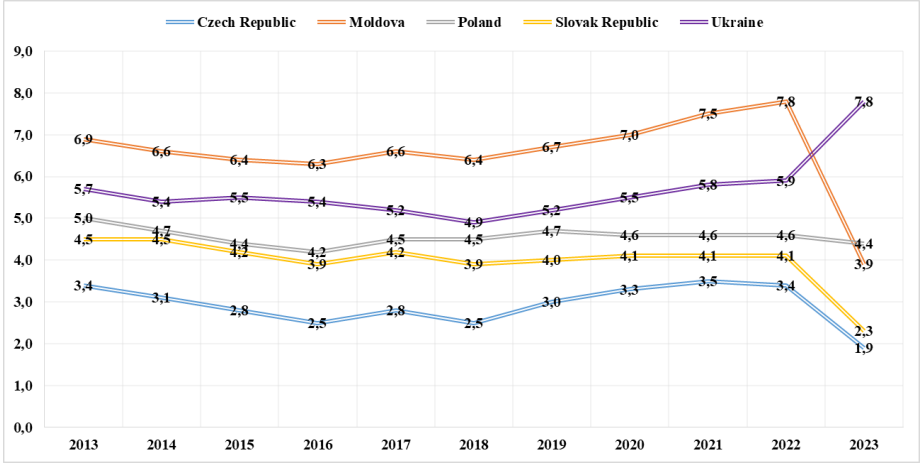


Figure 2. Human Flight and Brain Drain Index in Eastern Europe

Source: Developed by authors based on Fund for Peace, 2023.

Moreover, Ukraine’s ICT sector relies on a stable and growing job market, but during the war, IT companies stop hiring or reduce their workforce, limiting job opportunities for professionals. Particularly, the study by Work.ua (2023) reveals a significant decline in job vacancies in Ukraine’s ICT sector during the war, which continued throughout 2022. However, by June 2023, the situation improved, reaching 57% of pre-war levels, compared to 90% for the overall labor market in Ukraine. The majority of job offers were concentrated in Kyiv, Lviv, Dnipro, Odesa, and Kharkiv regions. The distribution of job vacancies also shifted, with IT company vacancies decreasing from 44% in February 2022 to 31% in June 2023, while vacancies in other categories increased. Finally, according to Djinni (2023) analytics, salaries for experienced technicians hired in 2023 are 500 USD lower on average than in 2022, what motivates IT professionals to look for a job abroad.

Noteworthy, in the first half of 2023, Ukraine's ICT service export declined by 3.9 billion USD, due to a significant emigration of Ukrainians since February 2022, who are primarily capable working individuals and could contribute to Ukraine's economic recovery. Therefore, the prospects for the future of the Ukraine’s ICT sector, in the absence of concerted efforts between the government and the technology industry to address crucial ICT-related challenges, appear, at best, insufficiently proactive. Although the ICT sector will not cease to exist entirely, it will regrettably miss the opportunity to position Ukraine as a frontrunner in the production of innovative solutions for an extended period.

Consequently, strengthening Ukraine's ICT sector competitiveness during and after a war demands a diversified approach focused on human capital development and talent retention.

Firstly, Ukraine’s state authorities should invest in ICT education from primary to higher education, collaborate with universities and vocational institutions to develop curricula, and offer scholarships to talented students pursuing ICT-related degrees.

Secondly, returnee programs should attract Ukrainian tech professionals who left during the war, providing incentives like tax breaks and housing support.

Thirdly, tech academies, internship programs, and apprenticeships should be formed through public-private collaborations, as well as mentorship networks should be established to link experienced professionals with young talents.

Fourthly, industry-academia collaboration should be encouraged, with research centers and joint projects addressing industry challenges (in addition to tech clusters and hubs to foster collaboration and innovation in ICT).

Finally, remote work policies should be promoted to tap into a global talent pool, and international internships and exchange programs should be facilitated.

5. Conclusions

The conducted research proves the low ability of the IT sector of Ukraine to compete with most countries in Eastern Europe, especially with the regional leaders - the Czech Republic, Poland, Hungary and Slovakia. In particular, a common feature among the region's leaders is OECD membership, which potentially provides competitive advantages, such as: firstly, strong ties to global technology markets, which provides a wider customer base and more opportunities for the growth and expansion of the IT sector through the effect scale, attracting investment and R&D; secondly, significant investment in ICT infrastructure (broadband, data centers and digital technologies) that facilitates effective communication, expands digital capabilities and supports the development of advanced ICT services; thirdly, a high-quality system of technical education, which forms the personnel reserve of the IT sector; finally, a stable political and economic environment that reduces uncertainty and creates a favorable climate for innovation, investment and entrepreneurship in the IT sector.

Ukraine's ICT sector has competitive advantages in Eastern Europe (sufficiently developed, accessible and reliable ICT infrastructure, significant human resources and export volumes of ICT services), however, there are problems in the insufficient legislative framework for the protection of intellectual property rights, which in turn leads to a decrease in Ukraine's ICT sector innovative potential, a decrease in the volume of patents issued, and a decrease in the export of high-tech goods. In addition, during the entire period under study, significant problems are observed in Ukraine regarding the fight against corruption, ensuring the rule of law, the efficiency and quality of government policy, as well as guaranteeing security and the absence of violence in the state.

It is worth noting that the war in Ukraine added to already existing problems in the ICT sector and the business environment: first, physical damage to the ICT infrastructure, problems with electricity supply, Internet access, and cyber attacks; secondly, a significant lack of qualified IT workers due to mass migration for security and economic reasons; thirdly, a decrease in the number of new contracts and projects of domestic IT companies with foreign customers, due to the fears of the latter regarding untimely or improper fulfillment of contractual obligations by Ukrainian IT teams.

Strengthening Ukraine's ICT sector requires a multifaceted approach focused on human capital development and skill development, which includes investing in ICT training, attracting technicians, establishing technical academies and promoting collaboration between industry and academia. In addition, during the post-war period, it is necessary to emphasize the allocation of funds for the restoration of ICT infrastructure

and the development of broadband communications, to encourage private sector investment and to create innovation centers. Finally, to increase the competitiveness of Ukraine's IT sector, the government should simplify regulatory procedures, strengthen intellectual property laws, modernize data protection laws, support technology start-ups and work with the private sector to maintain a favorable business environment in the IT sector and successfully address industry challenges.

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Annex: ICT Indicators and Indicators of Economic Development

Table A1. 5 ICT Indicators and 6 Indicators of Development in year 2019

	ICT Indicators Z1 to Z5					Development Indicators					
	Z1 ICTI I1	Z2 HRI I2	Z3 BREI I3	Z4 RDI I4	Z5 ITII I5	Ph 19	Tyr 19	X2 voice	X4 peace	X5 pstab	X6 free
<i>Ukraine</i>	0.387	0.350	0.066	0.212	0.542	12809	11.4	4.28	3.35	2.2	5.4
<i>Romania</i>	0.644	0.422	0.523	0.178	0.502	29858	11.1	4.56	6.17	6.1	6.7
<i>Poland</i>	0.618	0.704	0.800	0.780	0.642	33121	12.5	5.76	6.19	6.1	6.9
<i>Czech R</i>	0.569	0.610	0.820	0.728	0.671	40981	12.7	6.92	6.68	6.9	7.4
<i>Hungary</i>	0.497	0.546	0.742	0.511	0.644	32554	12.0	6.16	6.27	6.5	6.7
<i>Moldova</i>	0.357	0.138	0.258	0.000	0.500	13022	11.7	4.08	5.23	4.2	6.1
<i>Slovak R</i>	0.642	0.416	0.730	0.315	0.657	31888	12.7	6.08	6.11	6.3	7.0
<i>Bulgaria</i>	0.640	0.268	0.643	0.240	0.512	23192	11.4	4.86	6.06	6.2	7.1

Source: ICT Indicators from tables 2 to 6. Development Indicators, elaborated by Guisan(2021) and (2024) from World Bank WDI and WGI and other international statistics. PH is real GDP per capita, in Dollars at 2017 international prices. Tyr is Total Years of average Schooling of adult population (25+). X2 to X6 are in decimal scales (0 minimum, 10 maximum), being X2=Voice of Citizens, X4=Political Stability, X5=Peace, X6=Economic Freedom.

Table A2. Correlations between ICT Indicators in year 2019

	Z1	Z2	Z3	Z4	Z5
Z1	1.0000	0.4521	0.7540	0.3939	0.2871
Z2	0.4521	1.0000	0.6905	0.9430	0.7888
Z3	0.7540	0.6905	1.0000	0.7402	0.7031
Z4	0.3939	0.9430	0.7402	1.0000	0.8294
Z5	0.2871	0.7888	0.7031	0.8294	1.0000

Note: Calculated from table A1.

Table A3. Correlations between indicators of Development

	PH19	TYR19	X2 Voice	X4 Peace	X5 Stability	X6 Freedom
PH19	1.0000	0.6447	0.8974	0.8328	0.8727	0.8478
TYR19	0.6447	1.0000	0.8377	0.4615	0.4691	0.5326
X2	0.8974	0.8377	1.0000	0.6671	0.7222	0.7321
X4	0.8328	0.4615	0.6671	1.0000	0.9852	0.9419
X5	0.8727	0.4691	0.7222	0.9852	1.0000	0.9591
X6	0.8478	0.5326	0.7321	0.9419	0.9591	1.0000

Note: Calculated from table A1.

Table A4. Correlations between ICT and Development indicators

ICT	PH19	TYR19	X2 voice	X4 peace	X5 stability	X6 freedom
Z1	0.6992	0.2411	0.4508	0.7068	0.7709	0.7975
Z2	0.8137	0.6019	0.7654	0.4650	0.5133	0.4769
Z3	0.9169	0.6531	0.8464	0.9153	0.9495	0.9344
Z4	0.7915	0.7118	0.8313	0.4994	0.5383	0.5633
Z5	0.7602	0.9114	0.9350	0.4484	0.5043	0.5041

Note_ Calculated from table A1.

Correlation of Development Indicators and ICT Indicators

Real Production per capita, PH19: highest correlation with z3 y z2

Educational Level (TYR19): highest correlation with z5.

Voice of Citizens (Quality of Government): highest correlation with z5, z4 and z3.

Peace: highest correlation with z5 and z3

Stability: highest correlation with z3 and z1

Freedom: highest correlation with z3 and z1.