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MODELING THE SYSTEM OF FACTORS INFLUENCING THE INTERNATIONAL COMPETITIVENESS OF UKRAINE'S ICT SECTOR

МОДЕЛЮВАННЯ СИСТЕМИ ФАКТОРІВ ВПЛИВУ НА МІЖНАРОДНУ КОНКУРЕНТОСПРОМОЖНІСТЬ ІТ-СЕКТОРУ УКРАЇНИ

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The article examines the structural and functional relationships among key determinants that shape the international competitiveness of Ukraine's ICT sector. The research methodology combines graph theory and the Laurent power series. The research offers a detailed framework for understanding competitiveness in the ICT sector, highlighting the systemic interdependence among infrastructure, human capital, regulatory and business conditions, innovation potential, and international integration. It is found that the factors of the business and regulatory environment, integration of Ukraine's ICT sector into international economic relations, and human capital have the greatest impact on the international competitiveness of the Ukrainian ICT sector. The practical value of the article lies in its applicability for strategic decision-making and policy formulation for strengthening Ukraine's ICT sector international competitiveness, as well as further academic research and practical evaluations in similar national or regional contexts.

Keywords: competitiveness, ICT sector, ICT infrastructure, human capital, business and regulatory environment, R&D, international economic relations, graph method, Laurent series.

У статті досліджено структурні та функціональні взаємозв'язки між ключовими детермінантами, що формують міжнародну конкурентоспроможність ІТ-сектору України. Актуальність дослідження зумовлена стратегічною важливістю ІТ-сектору для економічної стійкості та глобальної інтеграції України, особливо в контексті прискорення цифрової трансформації та подолання геополітичних викликів. Методологія дослідження поєднує теорію графів (для відображення та аналізу взаємозв'язків між ключовими групами факторів впливу) та степеневий ряд Лорана (для моделювання динаміки та інтенсивності цих взаємозв'язків). Дослідження пропонує детальну структуру для розуміння багатовимірної природи конкурентоспроможності ІТ-сектору, підкреслюючи системну взаємозалежність між ІКТ-інфраструктурою, людським капіталом, регуляторними та діловими умовами, інноваційним потенціалом та міжнародною економічною інтеграцією. З'ясовано, що найбільше на міжнародну конкурентоспроможність ІТ-сектору України впливають фактори ділового та регуляторного середовища, інтеграція ІТ-сектору України до міжнародних економічних відносин та людський капітал. Водночас встановлено, найменший вплив на конкурентні позиції вітчизняного ІТ-сектора впливають фактори, пов'язані з наукомісткістю національної економіки. Практична цінність статті полягає в тому, що вона може бути застосована для прийняття стратегічних рішень та формулювання політики з питань підсилення міжнародної конкурентоспроможності ІТ-сектору України. Надаючи математично обґрунтовану модель, отримані результати можуть бути використані при розробці цільових заходів, визначенні пріоритетів та розподілі ресурсів у національних стратегіях розвитку ІКТ. Нарешті, проведене нами дослідження також може послугувати основою для подальших академічних досліджень і практичних оцінок у подібних національних

або регіональних контекстах, зокрема для поглибленого аналізу регуляторного та інвестиційного середовища, кількісного моделювання причинно-наслідкових зв'язків, сценарного моделювання та прогнозування.

Ключові слова: конкурентоспроможність, IT-сектор, ІКТ-інфраструктура, людський капітал, ділове та регуляторне середовище, НДДКР, міжнародні економічні відносини, метод графів, ряд Лорана

Statement of the problem. The study of the system of factors affecting the international competitiveness of Ukraine's ICT sector is extremely relevant in the current geopolitical and economic context. The rapid digitalisation of all sectors of the national economy, accelerated by the urgent need to adapt to wartime conditions and the destruction of physical infrastructure, has elevated the role of the ICT sector to a strategic pillar of national resilience and recovery. Moreover, Russia's full-scale invasion of Ukraine has fundamentally changed the operating environment for Ukrainian ICT sector players.

In this context, a thorough systematic analysis of the factors shaping the international competitiveness of the Ukrainian ICT sector is extremely important, as such a study provides not only a deeper theoretical understanding of its structural dynamics, but also practical conclusions for policy makers, businesses and international partners.

Analysis of recent research and publications. In recent years, Ukraine's ICT sector has been regularly studied by Ukrainian scientists and industry experts, focusing on various aspects of its development (export potential, innovation capacity, regulatory environment, etc.). At the same time, works [1–4] modelled individual processes at the level of ICT companies and the level of the ICT sector of Ukraine. Additionally, studies [5–7] provided a theoretical and practical basis for the main groups of factors influencing the international competitiveness of the ICT sector of the national economy.

Highlighting previously unresolved parts of the overall problem. Despite the growing international importance of Ukraine's ICT sector, the academic discourse still lacks comprehensive analytical models that capture the complex, interrelated factors that influence its international competitiveness. Thus, the unresolved scientific problem is the need to develop and apply a formalised methodological framework based on the theory of graphs and Laurent power series to model and assess the system of factors that determine the international competitiveness of Ukraine's ICT sector in order to identify critical nodes, structural dependencies and potential points of influence for its further strategic development.

Formation of the objectives of the article (task statement). The purpose of this article is to reflect and mathematically describe the system of factors affecting the international competitiveness of Ukraine's ICT sector using the method of graphs and Laurent power series to formally represent and analyse the complex interdependencies between the key determinants of its competitiveness.

Summary of the main research material. The study [5] considers and describes a number of principles for analysing the competitiveness of the ICT sector, according to which we will determine the components for further modelling the impact of factors on the formation and maintenance of the international competitiveness of the ICT sector of Ukraine (Table 1).

According to the study [6, p. 56], when assessing the ICT infrastructure factors, it is necessary to consider the criterion of demand for ICT, availability and accessibility of ICT, affordability of ICT, quality and security of ICT. Graphically (Figure 1), the model of interrelations and influence of individual factors on the formation of a reliable and uninterrupted ICT infrastructure is presented in the form of an oriented graph CIC1 (ICT infrastructure).

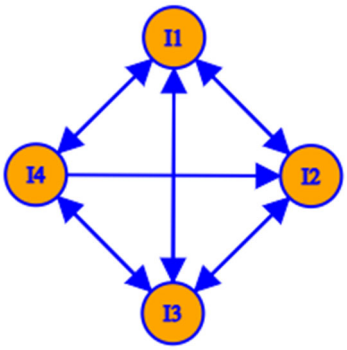

Figure 1. CIC1 factors interrelationships model

Source: developed by the authors

The directions of the edges of the elements of the graph CIC1 shown in Figure 1, the directions of the edges of the nodes (interconnections) of the elements of the graph CIC1 can be described

Table 1

Components of Modelling the System of Factors of International Competitiveness of the ICT Sector of Ukraine

Symbolic notation	Component of the analysis	Brief description of the structural components of competitiveness
CIC1	ICT infrastructure	In the assessment and modelling, they are the physical and technological capabilities required to support ICT sector: – **I1 (Demand for ICT)** reflects the degree of acceptance of ICT by the population and businesses; – **I2 (Availability)** assesses how accessible and geographically widespread the ICT infrastructure is; – **I3 (Quality)** reflects the ability of the infrastructure to support bandwidth-intensive software products; – **I4 (Reliability)** ensures the resilience and security of the ICT infrastructure.
CIC2	Human capital	In the assessment and modelling, it is the skills, experience and innovation capabilities of the workforce: – **HC1(General)** reflects the overall quality, availability and development of human capital in a country; – **HC2 (ICT-talents)** assesses the specialised skills and abilities of the workforce specifically related to ICT.
CIC3	Business and regulatory environment	It is assessed and modelled by the degree to which the ease of doing business in the ICT sector is facilitated by government policies, regulations and a stable business climate: – **BR1 (Business Environment)** assesses the overall quality and stability of the business ecosystem; – **BR2 (Government Regulation of the ICT Sector)** focuses on how government policies and regulations affect the ICT sector; – **BR3 (Taxes)** assesses fiscal policies and tax regime; – **BR4 (Investment Climate)** assesses a Ukraine's ability to attract and retain investment.
CIC4	R&D activity and innovation potential	In the assessment and modelling, it is the innovation potential of the ICT sector: – **RD1 (Overall Knowledge Intensity of the Economy)** measures a Ukraine's overall ability to support knowledge-intensive industries; – **RD2 (Innovation Potential of the ICT Sector)** focuses on the ability of the ICT sector to create and commercialise innovative technologies.
CIC5	Involvement of the ICT sector in the global ICT market	The assessment and modelling include the integration of the ICT sector into global value chains and international cooperation: – **ITI-1 (Foreign trade)** reflects the ability of the ICT sector to produce competitive products and services; – **ITI-2 (Membership in international organisations, blocs, alliances, etc.)** reflects the degree to which a country is integrated into the international ICT ecosystem.

Source: compiled by the authors

as follows (Table 2): higher ICT demand drives investment in ICT infrastructure development and modernisation (***I1*** → ***I2***); growing ICT demand increases the need for better network performance (***I1*** → ***I3***); more ICT use raises the need for secure and reliable infrastructure (***I1*** → ***I4***); greater ICT infrastructure availability boosts ICT consumption (***I2*** → ***I1***); expansion of ICT infrastructure includes improving network performance (***I2*** → ***I3***); higher-quality ICT services attract more broadband users (***I3*** → ***I1***); Internet providers modernise ICT infrastructure to maintain their competitive advantage (***I3*** → ***I2***); better networks require stronger security and data protection measures (***I3*** → ***I4***); a secure ICT environment builds user trust and increases demand for adoption and use of ICT (***I4*** → ***I1***); ensuring security and reliability

requires ICT infrastructure investment, which may affect the affordability of ICT services (***I4*** → ***I2***); increased security and reliability contribute to the maintenance of high-quality ICT services (***I4*** → ***I3***).

The assessment of the group of ICT infrastructure factors (CIC1) can be displayed in the form of formula 1.

$$L_1 = \sum_{2018}^{2022} \frac{\left(\sum_{n=1}^{12} \left(\frac{k_n}{k_{nmax}} \right) + \sum_{n=13}^{19} \left(\frac{k_{min}}{k_n} \right) + \sum_{n=20}^{21} \left(\frac{k_n}{k_{nmax}} \right) \right)}{5} = 6{,}880 \quad (1)$$

where, L_1 – assessment of a group of factors; k_n – element of the indicator of Ukraine; k_{max} – maximum global value of the indicator; k_{min} – minimum global value of the indicator.

Graphically, the model of interrelations and the impact of individual factors on the formation of qualified and competent human capital as components of the impact on the international competitiveness of Ukraine's ICT sector can be represented as an oriented graph CIC2 (Figure 2). In particular, the edges of the nodes

Table 2

Matrix of CIC1 indicators of Ukraine's ICT sector

Indicator / Year	Notation	2018	2019	2020	2021	2022	Average
Demand for ICT (I1)							
active mobile-broadband subscriptions per 100 inhabitants	k_1	0,242	0,378	0,395	0,358	0	0,275
fixed broadband subscriptions (>10 Mbit/s)	k_2	0,013	0,014	0,015	0,014	0,012	0,014
fixed broadband subscriptions per 100 inhabitants	k_3	0,281	0,345	0,392	0,375	0	0,279
households with a computer (%)	k_4	0,670	0	0,720	0	0	0,278
households with Internet access at home (%)	k_5	0,622	0,660	0,794	0,828	0	0,581
% of Internet users	k_6	0,652	0,729	0,776	0,811	0	0,594
monthly fixed broadband traffic per subscription	k_7	0	0	0	0	0	0
monthly mobile broadband traffic per subscription	k_8	0	0	0	0	0	0
total fixed broadband subscriptions	k_9	0,013	0,015	0,016	0,014	0,012	0,014
Availability (I2)							
population covered by a mobile-cellular network (%)	k_{10}	0,999	0,999	0,999	0,999	0,999	0,999
population covered by at least a 3G mobile network	k_{11}	0,900	0,891	0,891	0,916	0,910	0,902
population covered by at least a 4G mobile network	k_{12}	0,030	0,781	0,872	0,916	0,910	0,702
fixed broadband basket as a % of GNI p.c.	k_{13}	0,250	0,278	0,313	0,278	0,211	0,266
mobile broadband basket as a % of GNI p.c.	k_{14}	0,250	0,167	0,133	0,067	0,077	0,139
mobile cellular basket as a % of GNI p.c.	k_{15}	0,077	0,077	0,063	0,067	0,077	0,072
mobile data and voice basket (high consumption) as a % of GNI p.c.	k_{16}	0,231	0,231	0,167	0,118	0,133	0,176
mobile data and voice basket (low consumption) as a % of GNI p.c.	k_{17}	0,154	0,154	0,125	0,133	0,154	0,144
average cost of broadband Internet access	k_{18}	1	1	1	1	1	1
average cost of mobile Internet access	k_{19}	0,504	0,044	0,189	0,071	0,097	0,181
Quality (I3)							
mean download speed	k_{20}	0,187	0,109	0,137	0,235	0,390	0,212
Reliability (I4)							
secured Internet servers	k_{21}	0,059	0,060	0,063	0,054	0,042	0,055

Source: calculated by the authors by [8–10]

of the CIC2 graph (human capital) reflect the interaction between HC1 and HC2, which forms a dynamic system where the improvement of one element affects the development of the other (Figure 2).

Figure 2. CIC2 factors interrelationships model

Source: developed by the authors

Accordingly, a strong overall human capital situation in Ukraine will provide the necessary basis for the development of ICT talent (***HC1*** → ***HC2***), while the development of ICT talent would also contribute to the improvement of overall human capital indicators by strengthening the economy, increasing employment opportunities and improving the quality of education (***HC2*** → ***HC1***). The assessment of the human capital group of factors (Table 3) can be shown in the form of formula 2.

$$L_2 = \sum_{2018}^{2022} \frac{\left(\sum_{n=1}^{3}\left(\frac{h_n}{h_{nmax}}\right) + \sum_{n=4}^{4}\left(\frac{h_{min}}{h_n}\right) + \sum_{n=5}^{13}\left(\frac{h_n}{h_{nmax}}\right)\right)}{5} = 7{,}152 \quad (2)$$

where, L_1 – assessment of a group of factors; h_n – element of the indicator of Ukraine; h_{nmax} – the highest global value of indicator; h_{nmin} – the lowest global value of indicator.

The graphical model of interrelations and influence of individual factors on the formation of a favourable business and regulatory environment as components of the impact on the international competitiveness of the ICT sector of Ukraine is presented in the form of an oriented graph CIC3 in Figure 3.

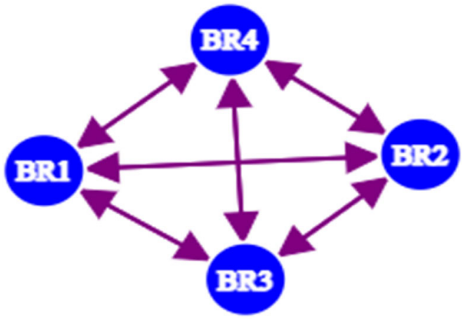

Figure 3. CIC3 factors interrelationships model

Source: developed by the authors

The directions of the edges of the nodes (interconnections) shown in Figure 3, of the CIC3 graph (business and regulatory environment) for Ukraine can be described by the following statements: strong business conditions support better governance, regulation, and cybersecurity

Table 3

Matrix of CIC2 indicators of Ukraine's ICT sector

Indicator / Year	Notation	2018	2019	2020	2021	2022	Average
General (HC1)							
Human Development Index	h_1	0,789	0,806	0,796	0,782	0,759	0,787
the number of employed highly qualified specialists	h_2	0,086	0,085	0,081	0,086	0	0,068
adult literacy rate (%)	h_3	0,998	0,998	0,998	1	1	0,999
Human Flight and Brain Drain Index	h_4	0,245	0,212	0,145	0,121	0,102	0,165
education spending (% of GDP)	h_5	0,696	0,712	0,678	0,774	0,918	0,756
education spending (% of government spending)	h_6	0,687	0,761	0,615	0,696	0,421	0,636
PISA results in mathematics	h_7	0,766	0,766	0,766	0,766	0,767	0,767
ICT talents (HC2)							
population with advanced ICT skills (%)	h_8	0,041	0,049	0,087	0,075	0,047	0,060
average salary in the ICT sector (PPP)	h_9	0,261	0,315	0,233	0,345	0,333	0,298
English Proficiency Index	h_{10}	0,747	0,742	0,776	0,792	0,815	0,775
business skills rank	h_{11}	0,190	0,290	0,367	0,212	0,563	0,324
technology skills rank	h_{12}	0,500	0,950	0,930	0,949	0,949	0,856
data science rank	h_{13}	0,460	0,530	0,820	0,827	0,684	0,664

Source: calculated by the authors by [8–9; 11–17]

(***BR1*** → ***BR2***); transparent and well-regulated business environment promotes fair, stable and competitive tax policy (***BR1*** → ***BR3***); favourable business environment attracts FDI by enhancing investor confidence and stability (***BR1*** → ***BR4***); ICT regulation and cybersecurity improve business reliability in ICT sector (***BR2*** → ***BR1***); ICT regulation can influence tax policies and incentives (***BR2*** → ***BR3***); effective regulation boosts investor confidence and FDI inflow in Ukraine (***BR2*** → ***BR4***); favourable taxes support ICT business and economic growth (***BR3*** → ***BR1***); tax privileges or burdens may affect the effectiveness of ICT sector regulation, affecting its financial performance (***BR3*** → ***BR2***); lower and predictable tax rates attract foreign investors (***BR3*** → ***BR4***); FDI fosters economic growth and improves institutional quality (***BR4*** → ***BR1***); more ICT investment motivates stronger regulation and policies (***BR4*** → ***BR2***); FDI attraction requires supportive tax reforms (***BR4*** → ***BR3***).

The assessment of the CIC3 group of factors (Table 4) for Ukraine can be shown in the form of formula 3.

$$L_3 = \sum_{2018}^{2022} \frac{\left(\sum_{n=1}^{3} \left(\frac{m_n}{m_{nmax}} \right) + \sum_{n=4}^{4} \left(\frac{m_{min}}{m_n} \right) + \sum_{n=5}^{17} \left(\frac{m_n}{m_{nmax}} \right) \right)}{5} = 511{,}54 \quad (3)$$

where, L_3 – assessment of the group of factors; m_n – the indicator of Ukraine; m_{nmax} – maximum world value of the indicator; m_{nmin} – minimum world value of the indicator.

The conceptual feasibility of including both general knowledge intensity indicators and ICT-specific innovation outcomes lies in their role as fundamental and direct determinants of the innovation potential of the ICT sector. Graphically, the model of interrelations and influence of individual factors on the formation of knowledge intensity and innovation environment of the ICT sector in Ukraine, as components of the impact on its international competitiveness, can be represented as an oriented graph CIC4 (Figure 4):

In particular, the edges of the nodes in the CIC4 graph (R&D activity and innovation potential) reflect the interaction between ***RD1*** and ***RD2***, which form a mutually reinforcing cycle. A higher level of overall knowledge intensity of

Table 4

Matrix of CIC3 indicators of Ukraine's ICT sector

Indicator / Year	Notation	2018	2019	2020	2021	2022	Average
Business Environment (BR1)							
Corruption Perceptions Index	m_1	0,376	0,349	0,388	0,364	0,379	0,371
International Property Rights Index	m_2	0,493	0,509	0,516	0,547	0,487	0,510
Index of Economic Freedom	m_3	0,575	0,580	0,614	0,627	0,641	0,607
Regulatory quality index	m_4	0,433	0,448	0,424	0,424	0,406	0,427
Government effectiveness index	m_5	0,371	0,386	0,376	0,352	0,330	0,363
Political stability index	m_6	0,057	0,092	0,126	0,130	0,058	0,093
GovTech Maturity Index	m_7	0	0	0,545	0,545	0,774	0,373
Government Regulation of the ICT Sector (BR2)							
ICT Regulatory Tracker	m_8	0,778	0,788	0,788	0,788	0,788	0,786
Global Cybersecurity Index	m_9	0,710	0,710	0,659	0,659	0,659	0,680
Taxes (BR3)							
corporate tax rate	m_{10}	0,500	0,500	0,500	0,500	0,500	0,500
social security rate for companies	m_{11}	0,102	0,080	0,080	0,080	0,080	0,085
social security rate for employees	m_{12}	0,102	0,080	0,080	0,080	0,080	0,085
sales tax rate	m_{13}	0	0	0,350	0,350	0,050	0,150
Investment Climate (BR4)							
Inward FDI flows	m_{14}	5	6	0	7	1	3,8
Inward FDI stocks	m_{15}	44,63	54	52	66	51	234,46
Inward FDI stocks (% of GDP)	m_{16}	35,83	35,23	33,26	32,91	31,77	33,80
Inward FDI stocks (% of GFCF)	m_{17}	202,71	199,55	248,20	248,71	273,11	234,46

Source: calculated by the authors by [8; 18–24]

the economy (***RD1***) has a positive impact on the innovation potential of Ukraine's ICT sector (***RD2***), at the same time the innovation potential of Ukraine's ICT sector ***(RD2***) also contributes to the overall knowledge intensity of the economy (***RD1***).

Figure 4. CIC4 factors interrelationships model

Source: developed by the authors

The assessment of the group of factors of R&D activity and innovation potential (Table 5) of the ICT sector in Ukraine can be shown in formula 4.

$$L_3 = \sum_{2018}^{2022} \frac{\left(\sum_{n=1}^{5} \left(\frac{d_n}{d_{nmax}} \right) \right)}{5} = 0{,}199 \qquad (4)$$

where, L_3 – the score of the group of factors; d_n – the element of the indicator of Ukraine; d_{nmax} – the maximum global value of the indicator o.

Considering the indicators of foreign trade and membership in international ICT organisations is conceptually necessary and methodologically appropriate for modelling the degree of integration of Ukraine's ICT sector into global economic relations, as these indicators reflect real interaction, covering both economic and institutional dimensions of integration. Graphically, the model of interconnections of individual factors of Ukraine's ICT sector integration into the global ICT market, as components of the impact on its international competitiveness, can be represented as an oriented graph CIC5 (Figure 5).

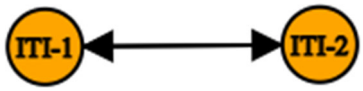

Figure 5. CIC5 factors interrelationships model

Source: developed by the authors

The directions of the edges of the nodes (interconnections) of graph CIC5 (involvement of Ukraine's ICT sector in the global ICT market) shown in Figure 5 can be described as follows: 1) exports and imports of ICT goods and ICT services affect Ukraine's ability and need to become a member of international organisations and alliances in order to facilitate market access, align national standards with the best international practices, and protect its trade and economic interests (***ITI1*** → ***ITI2***); 2) participation in international organisations and alliances improves the Ukraine's position in the global ICT market, positively influencing the terms of trade, reducing barriers and enhancing regulatory harmonisation (***ITI2*** → ***ITI1***).

The assessment of the group of factors of Ukraine's ICT sector's involvement in the global ICT market (Table 6) is shown in formula 5.

$$L_5 = \sum_{2018}^{2022} \frac{\left(\sum_{n=1}^{2} \left(\frac{w_n}{w_{nmax}} \right) + \sum_{n=3}^{4} \left(\frac{w_{min}}{w_n} \right) + \sum_{n=5}^{16} \left(\frac{w_n}{w_{nmax}} \right) \right)}{5} = 9{,}239 \qquad (5)$$

where, L_5 – the score of the group of factors; w_n – the indicator of Ukraine; w_{nmax} – the maximum global value of the indicator; w_{nmin} – the minimum global value of the indicator.

After characterising, calculating and modelling the graphs of individual components of the international competitiveness of Ukraine's ICT sector (CIC1...CIC5), the next important step is to build a complex oriented graph (CIC) of the relationships between these groups of

Table 5

Matrix of CIC4 indicators of Ukraine's ICT sector

Indicator / Year	Notation	2018	2019	2020	2021	2022	Average
Overall Knowledge Intensity of the Economy (RD1)							
researchers per million inhabitants	d_1	0,125	0,106	0,098	0,083	0,062	0,095
GERD (% of GDP)	d_2	0,099	0,083	0,071	0,068	0,054	0,075
high-tech export	d_3	0,0017	0,0016	0,0016	0,0014	0,0012	0,0015
Innovation Potential of the ICT Sector (RD2)							
number of issued patents in ICT	d_4	0,001	0,0003	0,00003	0,0001	0,00002	0,0003
number of scientific publications in ICT	d_5	0,028	0,0303	0,0330	0,0290	0,019	0,028

Source: calculated by the authors by [9; 12; 25–26]

Table 6

Matrix of CIC5 indicators of Ukraine's ICT sector

Indicator / Year	Notation	2018	2019	2020	2021	2022	Average
Foreign trade (ITI1)							
ICT goods exports	w_1	0,00068	0,00062	0,00051	0,00052	0,00069	0,00061
ICT services exports	w_2	0,031	0,033	0,033	0,035	0,036	0,034
ICT goods imports	w_3	0,070	0,059	0,079	0,078	0,134	0,084
ICT services imports	w_4	0,147	0,137	0,110	0,092	0,120	0,121
Membership in international organisations, blocs, alliances, etc (ITI2)							
WTO	w_5	1	1	1	1	1	1
OECD	w_6	0	0	0	0	0	0
ITU	w_7	1	1	1	1	1	1
WIPO	w_8	1	1	1	1	1	1
GPAI	w_9	0	0	0	0	0	0
FIRST	w_{10}	1	1	1	1	1	1
ICC	w_{11}	1	1	1	1	1	1
GSMA	w_{12}	1	1	1	1	1	1
ISO	w_{13}	1	1	1	1	1	1
UNESCO	w_{14}	1	1	1	1	1	1
ITSO	w_{15}	0	0	0	0	0	0
IMSO	w_{16}	1	1	1	1	1	1

Source: calculated by the authors by [20; 27]

factors as part of a comprehensive model of its international competitiveness (Figure 6).

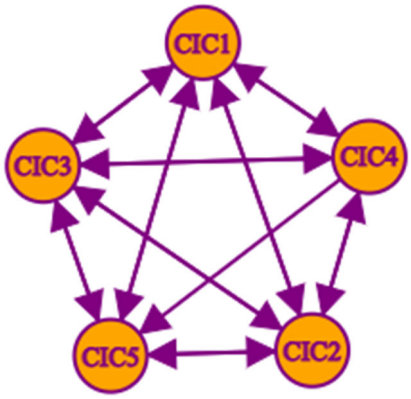

Figure 6. Graph of interconnections of groups of factors of Ukraine's ICT sector international competitiveness (CIC)

Source: developed by the authors

At the same time, the matrix of interrelations of groups of factors of international competitiveness of Ukraine's ICT sector in formula 6 is presented as a function that depends on the structural components listed in Table 1.

$$CIC = f_1\left(CIC1, CIC2 \ldots CIC5\right) = \sum_{i=1}^{5} CIC_i \quad (6)$$

where, CIC_i – component of Ukraine's ICT sector international competitiveness.

By using the Laurent series, we can present the system of analysed impacting factors of Ukraine's ICT sector in the form of a complex function (formula 7).

$$F\left(x\right) = \sum_{n=1}^{5} L_n = 535.01 \quad (7)$$

where, n – number of members of a number series; L_n – member of a series.

The directions of the node edges (interconnections) in the graph of international competitiveness of Ukraine's ICT sector, shown in Figure 6, can be summarised as follows: ICT infrastructure supports human capital via access to digital tools, online education, and remote work, etc. (***CIC1*** → ***CIC2***); robust ICT infrastructure is necessary for the efficient operation of ICT companies and compliance with digital regulations (***CIC1*** → ***CIC3***); ICT infrastructure fosters innovation and supports R&D activities (***CIC1*** → ***CIC4***); strong ICT infrastructure enables ICT exports and global

integration of Ukraine's ICT sector (***CIC1*** → ***CIC5***); skilled ICT professionals develop and maintain ICT infrastructure (***CIC2*** → ***CIC1***); digital competencies shape ICT policy and regulation (***CIC2*** → ***CIC3***); skilled human capital drives R&D and tech innovation in the ICT sector (***CIC2*** → ***CIC4***); skilled labour enables exports and international cooperation in ICT (***CIC2*** → ***CIC5***); stable regulation promotes sustainable ICT infrastructure investment and quality (***CIC3*** → ***CIC1***); state policies shape education and workforce development (***CIC3*** → ***CIC2***); incentives and support policies foster investment in R&D and innovations in ICT sector (***CIC3*** → ***CIC4***); regulation aligned with global standards supports foreign trade and investments in Ukraine's ICT sector (***CIC3*** → ***CIC5***); innovation demands ICT infrastructure expansions and upgrades (***CIC4*** → ***CIC1***); R&D drives demand for highly skilled ICT professionals (***CIC4*** → ***CIC2***); strong R&D sector requires the support of policies that protect IP, fund research initiatives and encourage cooperation (***CIC4*** → ***CIC3***); strong innovation potential would enhance Ukraine's global competitiveness in ICT (***CIC4*** → ***CIC5***); foreign trade in ICT services motivates the modernisation of Ukraine's ICT infrastructure through the import of advanced technologies and international cooperation (***CIC5*** → ***CIC1***); Ukraine's integration into the global ICT market requires a highly skilled labour force, which in turn requires investment in education and professional development, as well as the attraction of specialists from abroad (***CIC5*** → ***CIC2***); ICT trade requires regulatory alignment with global standards (***CIC*** → ***CIC3***).

Conclusions. Based on the results of calculations and modelling, we determined that the international competitiveness of Ukraine's ICT sector is most strongly influenced by the business and regulatory environment, which covers various aspects of regulation, political stability, tax burden and investment climate in Ukraine. The second most important factor was the foreign trade of Ukraine's ICT sector and its involvement in MEAs, followed by human capital, ICT infrastructure, and innovation potential. By visually depicting the connections between these groups, the graph method provided a clear picture of how different categories of factors interact. In conclusion, promising areas for further research on this topic will include in-depth analysis of the regulatory and investment environment, quantitative modelling of cause and effect relationships, scenario-based modelling and forecasting.

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