Effectiveness of cluster interaction of education, science and business stakeholders in the innovation ecosystem

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Abstract. The article considers the need for cluster interaction of stakeholders in education, science and business, which plays a key role in ensuring the innovative development of the economy. The mechanisms of stakeholder interaction through clustering are analysed, which contributes to the formation of a sustainable eco-system for the integration of knowledge, innovation and business processes. The advantages of cluster interaction are described, including the creation of a synergistic effect, improving the quality of education, commercialisation of scientific developments and increasing the competitiveness of the economy. The research investigates the development and effectiveness of clusters in Ukraine, particularly through the Ukrainian Cluster Alliance (UCA), and outlines examples such as the Lviv IT Cluster, Kharkiv IT Cluster, IT Dnipro Community, Kyiv IT Cluster, and Odesa IT Family. Using multi-criteria analysis (MCA), the clusters are evaluated based on institutional structure, financial mechanisms, innovative outputs, economic impact, and replicability. The challenges associated with clustering are considered, and prospects for improving interaction in terms of state support for innovative development are proposed. The study reveals the potential of cluster models to develop innovation ecosystems, increase regional economic competitiveness and support sustainable development. It suggests that Ukraine's experience with cluster development can serve as a basis for wider application, offering strategies to strengthen stakeholder engagement and promote innovative growth.

Keywords: Education, Science and Business, Stakeholder, Cluster Interaction

1 Introduction

In the modern globalised world, sustainable economic development is impossible without the production of new technologies and knowledge. The main role in the production of new technologies and knowledge is played by science, which creates new knowledge, and education, which trains new highly qualified personnel. But knowledge alone, without its integration into the business environment, has no economic impact. It is the formation of close interaction and cooperation between education, science and business, ensuring their interaction in the ecosystem that will organically combine the functioning of each of these areas of activity in the market. This will help to develop an innovative model of the economy in Ukraine, improve the living conditions of the population and ensure the overall stable development of society. The interaction of science, education and business involves combining various areas of economic and social activity into a single, holistic ecosystem. Establishing close cooperation between stakeholders, taking into account joint activities, to effectively perform their functions and achieve their goals is possible using available resources and management mechanisms. From an economic point of view, the interaction of education, science and business is the accumulation of resources for the development of the innovation economy, such as:

increasing the level of solving social problems and tasks;

building trust between stakeholders in their interaction;

creation of new quality services and products;

bridging the gap between scientific and educational institutions in the performance of socially important economic functions;

transfer and dissemination of knowledge;

ensuring sustainable development of the country's scientific and educational system,

creation of appropriate complexes capable of acting effectively and successfully performing both research and educational tasks [1].

Thus, the interaction of education, science and business stakeholders allows them to gain their own advantages and ensure a synergistic effect. The positive effects of effective stakeholder interaction indicate that it is of great importance for socio-economic development, and therefore should be initiated and supported at the state and local levels to exchange ideas, knowledge and experience.

2 Literature review

The modern innovation economy is a new economic formation that replaces the industrial economy. It emerged in the United States in the late 50s of the twentieth century on the basis of other schools of economic thought, including new institutional economics, new growth theory, endogenous growth theory, evolutionary economics, and Schumpeter's economics [2], which provides an economic framework that explains and supports growth. In the 60s of the twentieth century, a new concept of futurology appeared, named by the German scientist O. Flechtheim [3], which partially underlies the

formation of an innovative economy. This concept was developed by American futurists F. Fukuyama [4, 5] and E. Toffler [6].

The practical implementation of the concept of innovation economies is presented within the framework of the technical and technological paradigm, the paradigm of closed and open innovations by G. Chesbro [7, 8, 9], the triple helix model by G. Itzkowitz [10-16] and the theory of spatial diffusion of innovations by T. Hegerstrand [17], studies by G. Becker [18], T. Schultz [19], J. Minker [20, 21].

In the process of implementing the innovation economy, a whole range of interrelationships arises between different sectors of the country's economy: education and the labor market, production and information technologies, legislative decisions and financial institutions, environmental requirements, etc. E. G. Karayanis and D. F. J. Campbell [22], in characterizing the innovation economy, define that people, culture and technology meet and interact in it to stimulate creativity, invention and accelerate innovation in scientific and technological disciplines, public and private sectors (government, universities, industry and non-governmental organizations for the production, use and updating of knowledge).

Central to D. Bell's theory [23] is the concept of the dominance of science and knowledge as a basic prerequisite for economic growth in a globalized space. The scientist considers science as a prerequisite for the organization and structure of a new quality, and the main elements of such a system are research and educational institutions: universities, research institutes, academies, technology parks, etc.

The effectiveness of innovative ecosystems is important for sustainable entrepreneurship. Researchers propose to use a hierarchical decision-making model (HDM) to build a generalized framework for assessing the innovation economy to formulate ecosystem strategies for entrepreneurship and innovation [24].

The theory of the innovative economy and entrepreneurial society was formulated by the American scientist. P. Drucker in his works “Innovation and Entrepreneurship” [25] and “Post-Capitalist Society” [26], which emphasized the importance of interaction between science, education and business to achieve innovative development and competitiveness. The researcher believed that education should provide not only knowledge and skills, but also the ability to act in unstable and changing situations. To bridge the gap between theory and practice, the university incubates business ideas with the involvement of stakeholders. It is the inclusion of interdisciplinary experience that forms recommendations for the development of innovative programs that implement the interaction between the university, research institution and industry [27].

The Strategy for Sustainable Development “Ukraine - 2020” [28] states that one of the main elements of solving large-scale tasks of modernization of the country, ensuring the necessary defense capability and national security should be the creation of an effective system of interaction “science - education - economy - innovation”. The OECD Innovation Strategy [29] recognizes the education of consumers of innovations, citizens and companies that become active participants in the innovation process as one of the most important aspects of the innovative development of countries. The report of the European Association of Universities [30] identifies the following key roles of stakeholders in the innovation economy: education (development of human capital for inno-

vation), research (production of knowledge to create private and public value) and entrepreneurship (necessary for sustainable social change). Other important elements are the exchange of information resources for innovation systems (from technology transfer to multilateral co-generation), a source of public trust to ensure the sustainability of innovation systems: high social status and extensive strong and weak ties with actors in different sectors.

A cluster is an association of geographically concentrated groups of interconnected companies, specialised service providers, firms in contested industries, as well as related organisations (e.g. universities, standardisation agencies, and trade associations) in certain areas that compete and at the same time carry out joint activities [31]. One of the key aspects of M. Porter's cluster theory [32] is that a cluster is defined as a certain set of interconnected enterprises and other institutions that are able to produce a synergistic effect, which, in turn, strengthens and improves their position in the competition in the local environment of a particular country or region.

A study of the cluster life cycle will allow policy makers and stakeholders to more effectively tailor support mechanisms to the changing needs of clusters at different stages of development. Classifying the support needs of clusters according to their level of maturity in the life cycle will contribute to understanding cluster dynamics and the effectiveness of support policies. The key science-education-business stakeholders in the clusters themselves play an important role in the success of support programs, as they have valuable insights into the unique dynamics and requirements of the stakeholders [33].

The study of challenges and opportunities in the business-education-science system in the context of innovative development, which was carried out on the basis of cross-country cluster analysis, allowed to identify countries that have leadership in the interaction of education, science and business, such as the United States and China, whose experience can be useful for further development and management decisions at various levels of government in the context of innovative development, including through increased competition between business, education and science [34]. The study of local educational clusters involving universities in China showed that the triple helix model, which includes relations between education, science and industry, is effective. The exchange of resources, knowledge and experience, as well as the exchange of professional inclinations, skills and personal orientations between participants within local clusters, contribute to the enrichment of the educational environment for local universities. The business sector promotes innovation, technology adoption and market orientation in academia, and in the established educational clusters plays a key role in ensuring the required quality of human resources through university training. Close interaction between students, academia, companies, and research institutions creates a favorable environment that allows identifying opportunities and generating ideas through deep knowledge, skills, and experience [35].

French researchers note that partnerships in clusters go beyond national systems. They also highlight proactive spontaneous and organized cooperation in clusters of two types: clusters consisting only of business are noted, as well as clusters that have cooperation in education, science and business, examples of which in France are competitiveness clusters, the research triangle (USA), clusters of Japan, Belgium, Hungary, etc. [36].

The Polish monitoring of trends in innovation (2024) showed that in the UK, eight modern clusters were announced on the Launchpad innovation platform to support business with the participation of science and education, while in Poland, new clusters were noted in trade and industry: human potential, urban systems, sustainable resources and environment (WPP), modern services, lifestyle [37], which increases attention to the education-science-business chain as a means of ensuring competitiveness.

On the official website of the Verkhovna Rada of Ukraine [38], the term cluster is mentioned in the title of the documents only in three regulatory documents of the CMU, which relate to individual components of the cluster process, medical institutions, the national fair and arts and crafts. It is promising to increase attention to clusters and the potential for state regulation of this process in the Strategy for Digital Development of Innovation Activities of Ukraine until 2030 and the approval of an operational plan for its implementation in 2025-2027: CMU Order of December 31, 2024, No. 1351-r, which focuses on innovation clusters, partially reflects the requirements for them and further shows the need for education, science and business to unite for this purpose [39].

3 Purpose

The aim of the study is to identify strategic directions for the development of regional clusters, analyze the effectiveness of cluster interaction between education, science and business stakeholders, and develop recommendations for improving public policy to stimulate cooperation between educational, research institutions and business. The objectives of the study are as follows:

to assess the role of clusters in the interaction of education, science and business;

to analyze the development of clusters in Ukraine;

to identify key criteria that influence the success of interaction between education, science and business;

to assess the effectiveness of cluster interaction of education, science and business stakeholders in the innovation ecosystem;

to develop recommendations for the development of clusters and interaction between educational, scientific and business structures.

4 Methodology and research methods

In order to confirm the long-term stability of interest in the interaction of education, science and business and to identify the important role of cluster initiatives in the development of the innovation economy, the method of Internet analysis was used.

Google Trends (a tool for analyzing the popularity of search queries using Google) allows us to assess changes in search interest in the topic of interaction between education, science and business, as well as to determine its significance and relevance for different audiences. In this study, the authors used Google Trends to analyze search interest in the terms "education, science, business" and "cluster" over the past 20 years. The tool allows not only comparing the number of queries, but also determines the geographical distribution of interest, which allows exploring topics from different perspectives. The task includes:

analyzing changes in the popularity of the term "cluster" to identify the role of cluster initiatives as a mechanism for economic development, as well as their impact on the integration of education, science and business;

defining the relationship between the terms "education, science and business" and "innovation clusters" and studying how their relationship reflects the development of innovation in education, science and business through the clustering mechanism.

A multicriteria analysis (MCA) can be used to assess the effectiveness of cluster interaction between education, science and business in Ukraine [40]. This will allow comparing different clusters by the main parameters and identifying the strengths and weaknesses of each of them. The following steps were used to determine the assessment of the effectiveness of cluster interaction between education, research and business in Ukraine on the analysis:

formation of criteria for evaluating the effectiveness of cluster interaction between education, science and business stakeholders to ensure the development of the innovation ecosystem;

the calculation of the total score for effectiveness of each cluster, taking into account the weighting values, was carried out using the formula [41]:

$$S_i = \sum_{j=1}^{n} (w_j \cdot x_{ij}), \quad (1)$$

S_i – the total score for the i-th cluster, w_j – the weight of criterion j, x_{ij} – the value of criterion j for the i-th cluster.

5 Results

5.1 Terms of cluster interaction of education, science and business stakeholders in the innovation ecosystem

The search interest in "education science business" determined by the authors using the modern online system Google Trends (Fig. 1) over a long 20-year period is quite stable with minor fluctuations, which indicates a steady interest in the topic of integration of education, science and business for a long time, as well as its relevance for different audiences, including the educational, scientific and business communities. This may indicate that this topic is universal and remains important regardless of changes in external conditions, such as economic or technological trends.

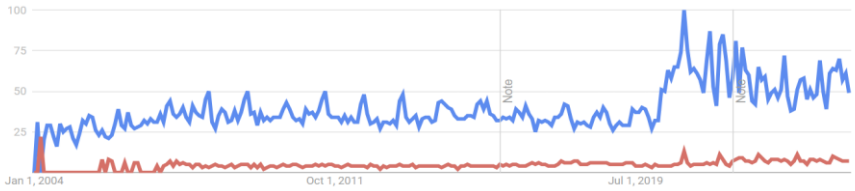

Fig. 1. Dynamics of search interest (Google Trends) to the terms “education science business” (red) and “clusters” (blue) in the world (2004 - present) [42]

The growing popularity of the term “cluster” can be attributed to the development of cluster initiatives in various sectors of the economy, including technology, industry and regional development. Clusters are often seen as an instrument for economic growth, which explains the increased interest. It is advisable to strengthen the emphasis on the integration of education, science and business within cluster interactions through the use of trendy terms (e.g., “innovation clusters”) (Fig. 2).

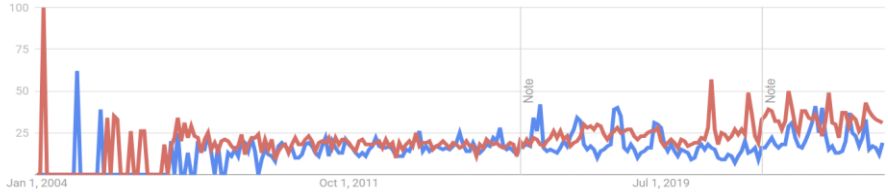

Fig. 2. Dynamics of search interest (Google Trends) in the terms “education science business” (red) and “innovation clusters” (blue) in the world (2004 - present) [43]

The dynamics of search trends for the terms “education science business” and “innovation clusters” (Fig. 2) demonstrates a long-term relationship, despite their separate thematic areas. The dynamic affinity lies in the fact that both terms reflect interest in innovation activities, in particular in the field of education, science, business and cluster development. Thus, the concept of ‘education science business’ can be strengthened by using a specific tool of innovation clusters, which have the potential to become a key mechanism in the system of interaction between science, education and business.

Clustering models demonstrate significant potential to influence regional economies through innovation and cooperation between education, science and business. Clustering involves the creation of networking between education, science and business stakeholders to improve the efficiency of their activities and achieve common goals (Table 1), which presents the characteristics of a particular stakeholder (sector) of cluster interaction in terms of interaction mechanisms and expected results.

Table 1. Characteristics of cluster interaction by an individual stakeholder

Sector	Stakeholder	Mechanisms	Expected results	Institutions
Education	University, school, educational foundation	Joint training programmes with business Internships in in real projects	Training of of specialists adapted to the to the labour market Improving the quality of education	Learning hubs Innovation campuses
Science	Scientific institute laboratory	Commercialisation of research Joint grant projects with business	Implementation of innovations in production Increasing funding for science	Spin-off companies Research consortia
Business	Corporation, start-up, industry association	Investments in innovative projects Educational grants and programmes	Access to new ideas and technologies Increasing productivity productivity	Start-up accelerators Industrial parks

Source: compiled by the authors based on [44, 45, 46]

The interaction of education, science and business creates a synergistic effect that ensures the development of the innovation ecosystem, increases the competitiveness of the economy and promotes sustainable development.

5.2 Analysis of cluster interaction in Ukraine

In August 2022, the Ukrainian Cluster Alliance (UCA) [47] presented a streamlined structure of clusters on its own information resource in the areas of EAM and Aerospace; Textile; Agri-food; Construction - Furniture; Traditional Industries; IT, Innovations and Creatives clusters; etc. The development of clusters in Ukraine dates back to the late 1990s, but in recent years it has gained a new and significant impetus. The active position of individual market participants and increased international donor support, in particular from GIZ, UNDP, and USAID, have contributed to the renewed cluster movement in Ukraine. In particular, in 2020, GIZ supported the cluster movement initiative and allowed the launch of a project to develop IAM (Engineering-Automation-Machinery) clusters in Kharkiv [48] and Zaporizhzhia [49] regions. The implementation of this project contributed not only to the development of cluster processes in these regions, but also to certain changes in innovation ecosystems, gradual rapprochement with regional authorities, and a powerful impact on the development of the cluster movement in Ukraine. In March 2022, UCA was launched, comprising about 35 clusters with more than 1,800 enterprises.

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participants and increased international donor support, in particular from GIZ, UNDP, and USAID, have contributed to the renewal of the cluster movement in Ukraine. Over the past few years, a community of stakeholders - education, science, and business - has been formed and gradually united into a number of cluster initiatives (Table 2).

Table 2. Evolution of cluster interaction in Ukraine in 2020-2024

Data	Result
2020	GIZ supported the cluster movement initiative and allowed the launch of a project to develop IAM (Engineering-Automation-Machinery) clusters in Kharkiv [48] and Zaporizhzhia [49] regions. The implementation of this project contributed not only to the development of cluster processes in these regions, but also to certain changes in innovation ecosystems, gradual rapprochement with regional authorities, and a powerful impact on the development of the cluster movement in Ukraine.
March 2022	The Ukrainian Cluster Alliance (UCA) [47] was founded, which includes about 35 clusters uniting more than 1,800 enterprises. The community covers various industries (engineering, machine building, textile, furniture and agricultural production, etc.), which are represented in almost all regions of Ukraine, unites a large number of business, educational and scientific structures, and has a large group of experts and teams capable of solving most current and strategic issues.
August 2022	On its website, the UCA presents an organized structure of clusters by area: 1) EAM and Areospace; 2) Textile; 3) Agri-food; 4) Construction - Furniture; 5) Traditional Industries; 6) IT, Innovations and Creatives clusters; 7) Other
2024	The UCA has expanded from 24 to 44 clusters, bringing together key industries, including energy, IT, agriculture, defense, and innovative technologies. The first 3 ESCA certifications are the beginning of the establishment of quality standards for the UCA

Source: compiled based on [44, 50,51]

The analysis of the evolution of cluster interaction in Ukraine in 2020-2024 (Table 2) shows a gradual growth and structuring of the cluster movement. The defining events of this period were the initiatives of international partners, the creation and expansion of the Ukrainian Cluster Alliance (UCA), and the introduction of quality standards for cluster activities.

Analysis by for criteria assessing the effectiveness of cluster interaction of education, science and business stakeholders in the innovation ecosystem. Clusters in Ukraine [47, 48, 49] have clear goals aimed at developing regional industries and improving the economic environment. For a deeper understanding, it is proposed to study each of these clusters according to the following criteria: institutional structure (number and types of stakeholders), financing mechanisms (government programmes, private investment), innovative results (number of patents, start-ups, new technologies), impact on the regional economy (jobs, regional GDP), replicability of the model (possibility of adaptation in other countries).

In terms of institutional structure, the clusters include educational institutions, local businesses of various sizes, regional authorities and NGOs. Kharkiv IT Cluster works closely with universities such as LNU and NULP. Kharkiv IT Cluster engages research institutes and technology parks in its work. IT Dnipro Community has close ties with local communities and entrepreneurs. The clusters are funded by grants from international organisations, private investments from member companies and budgetary funds. The Lviv cluster receives grants for educational programmes and innovative projects, while the Kharkiv IT Cluster cooperates with foreign donors to create educational platforms.

Joint educational programmes are an important mechanism for cluster interaction. For example, Lviv IT Cluster develops programmes for higher education students in Data Science and AI, while Kyiv IT Cluster assists universities in adapting curricula to business needs. In research, Kharkiv IT Cluster engages scientists in R&D projects, and Odesa IT Family creates accelerators for startups. The results of the clusters' activities demonstrate positive changes in the regions. Lviv IT Cluster has increased the number of IT professionals and launched more than 10 educational programmes. Kharkiv IT Cluster has contributed to increased employment in the IT sector, and IT Dnipro Community is actively introducing technological innovations in the agricultural sector. Social impacts include increased employment, higher incomes, and educated professionals.

The most promising model for adaptation in other regions is the Lviv IT Cluster model, due to its scalability and accessible structure. For regions with agrarian specialisation, the approach of IT Dnipro Community, which focuses on the specifics of local business, is useful. The Kyiv IT Cluster demonstrates high development dynamics due to its strong institutional base and access to finance. Kyiv IT Cluster has high potential, but requires significant investment in infrastructure modernisation, improved stakeholder interaction, and intensified innovation processes. However, clusters face a number of challenges. Financial constraints, including insufficient public funding, slow down development. Institutional obstacles include the lack of a legal framework for clustering, and cultural obstacles include a low level of trust between business and educational institutions. Prospects for cluster development are associated with expanding interregional cooperation, creating joint projects, and attracting venture capital funds and foreign partners. This approach will improve clustering models and increase the competitiveness of regions.

Assessment of effectiveness of cluster interaction of education, science and business stakeholders in the innovation ecosystem. According to the analysis of clusters in Ukraine, their quantitative indicators are determined according to the proposed criteria with the three-level structure (Table 3).

Table 3. Criteria for assessing the effectiveness of cluster interaction of education, science and business stakeholders in the innovation ecosystem

Criteria	1	2	3	Value, %
К1. Institutional structure	Weak	average	strong	20
К2. Financial mechanisms	limited	balanced	diverse	15
К3. Innovative results	Low	average	high	30
К4. Impact on the regional economy	limited	moderate	significant	25
К5. Replicability of the model	difficult adaptation	conditional	high	10

Source: calculated by the authors

The ranking of the criteria by importance (Table 3) is based on expert assessment, which takes into account the impact of each criterion on the effectiveness of cluster interaction between education, science and business. Innovative outputs are a key indicator of cluster success, as they reflect the ability to transform cooperation between education, research and business into real products, services or solutions. It is innovation that allows a cluster to be competitive and sustainable. Therefore, this criterion was assigned the highest weight (30%). The economic impact of the cluster (job creation, tax revenues, investment growth) demonstrates its practical significance for the region. Since clusters have a direct and indirect impact on the economy, this criterion was given a high weight (25%). A clear organisational structure ensures effective coordination between cluster members. Without a proper structure, even good funding or the potential of the participants may not be used effectively (20%). Stable funding is the basis for cluster functioning, but its impact is indirect. Not only the amount of funding is important, but also the transparency and efficiency of the distribution of funds, so the weight of this criterion is somewhat lower (15%). Replicability is important for scaling successful models to other regions. However, this is a secondary criterion, as the main focus is on the effectiveness of a particular cluster, so it has a weight of only 10%. The results of calculating the effectiveness of cluster interaction of education, science and business stakeholders to ensure the development of the innovation ecosystem are consistent with the current level of cluster interaction in Ukraine (Table 4).

Table 4. Calculating the effectiveness of cluster interaction of education, science and business stakeholders in the innovation ecosystem

Cluster	K1	K2	K3	K4	K5	Total Score
Lviv IT Cluster	5 × 0.2 = 1.0	4 × 0.15 = 0.6	5 × 0.3 = 1.5	5 × 0.25 = 1.25	5 × 0.1 = 0.5	4.85
Kharkiv IT Cluster	4 × 0.2 = 0.8	5 × 0.15 = 0.75	4 × 0.3 = 1.2	4 × 0.25 = 1.0	4 × 0.1 = 0.4	4.15
IT Dnipro Community	3 × 0.2 = 0.6	4 × 0.15 = 0.6	4 × 0.3 = 1.2	4 × 0.25 = 1.0	4 × 0.1 = 0.4	3.8
Kyiv IT Cluster	5 × 0.2 = 1.0	5 × 0.15 = 0.75	5 × 0.3 = 1.5	5 × 0.25 = 1.25	4 × 0.1 = 0.4	4.9
Odesa IT Family	3 × 0.2 = 0.6	3 × 0.15 = 0.45	3 × 0.3 = 0.9	4 × 0.25 = 1.0	3 × 0.1 = 0.3	3.25

Source: calculated by the authors

According to the results of the multi-criteria analysis (MCA) (Table 3), Kyiv IT Cluster and Lviv IT Cluster are the most efficient, having received 4.9 and 4.85 points respectively. The lowest efficiency is demonstrated by Odesa IT Family, which is due to a weak institutional framework and limited funding mechanisms. For clusters with low efficiency, such as Kyiv IT Cluster, it is advisable to use additional tools that will facilitate the interaction of cluster stakeholders and formulate development strategies, and apply start-up and small enterprise support programmes to strengthen the innovation ecosystem. It is also advisable to organise platforms for the exchange of knowledge and best practices between effective (Lviv and Kyiv) and other regional clusters and to hold joint conferences, seminars and trainings to improve the competence of cluster leaders and managers. Attracting additional sources of funding will help to increase the efficiency of clusters and improve their impact on the Ukrainian economy.

6 Conclusion

In the context of globalization, sustainable economic development is impossible without the production of new technologies and knowledge. Science and education play a key role in this process, but to achieve economic benefits, knowledge must be integrated into the business environment. Therefore, it is important to ensure close interaction between these sectors to create an innovative model of the economy. Clustering of educational, scientific and business institutions is an effective mechanism for achieving common goals, improving the quality of services and products, solving social problems and ensuring increased competitiveness. This allows for the creation of new ideas and technologies that contribute to economic development. The interaction of these three sectors contributes to the accumulation of resources for the development of the innovation economy, solving social problems, reducing the gap between scientific and educational institutions, and promotes the sustainable development of the scientific and educational system. Effective interaction between education, science and business creates a synergistic effect that ensures the development of the innovation ecosystem, increases

the competitiveness of the economy and contributes to the sustainable development of society. Interaction between these sectors should be initiated and supported at the state and local levels to ensure the exchange of ideas, knowledge and experience necessary for the effective development of the economy and society. In general, cluster interaction between education, science and business is an important tool for the development of an innovative economy.

An analysis of the dynamics of search queries according to Google Trends shows a steady interest in the integration of education, science, and business over the past 20 years. This emphasizes the relevance of this topic for various audiences, including educators, scientists, and entrepreneurs. The growing popularity of the term “cluster” indicates the development of cluster initiatives in various sectors of the economy, which are often seen as a tool for economic growth. The use of terms such as “innovation clusters” can strengthen the emphasis on the integration of education, science and business within cluster interactions. The relationship between the search queries “education, science, business” and “innovation clusters” indicates a common interest in innovation in these areas. This confirms the potential of innovation clusters as a key mechanism of interaction between science, education and business, which can contribute to the development of the innovation ecosystem and increase the competitiveness of regions. The analyzed experience of different countries has confirmed the existence of a general trend in cluster initiatives for targeted organized cooperation in the science-education-business chain, which contributes to their leadership.

The evaluation of the effectiveness of cluster interaction between education, science and business stakeholders was based on the analysis of five criteria (K1-K5), each of which had its own weight. Kyiv IT Cluster is highly effective in creating conditions for innovative development. All the criteria were assessed at the maximum level, except for K5 (an indicator of business cooperation activity). Lviv IT Cluster also demonstrates high efficiency, with strong links between education, science and business being the main advantage, which contributes to the development of the innovation ecosystem. Kharkiv IT Cluster and IT Dnipro Community demonstrate a moderate level of efficiency. The main shortcomings are related to slightly lower indicators of cooperation between stakeholders and the level of innovation activity. Odesa IT Family's score indicates significant problems in interaction between stakeholders, insufficient activity in attracting educational and scientific resources, and weak coordination of innovation activities. The criteria with the highest weighting coefficients (K3 - the link between science and business, and K4 - the level of innovation activity) have the greatest impact on the overall result. The leaders of the ranking demonstrate high performance in these criteria, which indicates their decisive influence on cluster efficiency. The analysis shows that Kyiv IT Cluster and Lviv IT Cluster are the most effective in ensuring the development of the innovation ecosystem through synergies between education, science and business. For other clusters, it is advisable to use the experience of the leaders, adapting their approaches to local conditions, to improve their performance.

Prospects for further research could include analyzing the mechanisms of financing cluster initiatives, studying the effectiveness of state policy to support clustering, and comparing Ukrainian experience with the best international practices. An important area is to study the impact of digitalization on cluster development, in particular the

integration of intelligent technologies, artificial intelligence, and big data into cluster interaction processes. It is also relevant to study interregional and international cooperation of clusters, which will allow developing recommendations for strengthening their competitiveness. Further analysis may include an assessment of the socio-economic impact of clusters on regional development, employment, and innovation activity of enterprises.

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