https://doi.org/10.33271/nvngu/2026-4/174

I. Riepina[1],
orcid.org/0000-0001-9141-0117,
M. Tepliuk[*1,2],
orcid.org/0000-0001-6823-336X,
T. Shkoda[1],
orcid.org/0000-0003-1016-4853,
N. Yakusheva[1],
orcid.org/0000-0001-9511-2723,
K. Nemashkalo[3],
orcid.org/0000-0002-8614-750X,
V. Onyshchenko[4],
orcid.org/0000-0001-9301-2518

1 – Kyiv National Economic University named after Vadym Hetman, Kyiv, Ukraine
2 – SCIRE Foundation, Warsaw, Poland
3 – Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine
4 – Educational and Scientific Institute "Prydniprovsk State Academy of Construction and Architecture", Ukrainian State University of Science and Technology, Dnipro, Ukraine
* Corresponding author e-mail: maria_6.11@kneu.edu.ua

FORECASTING THE DEVELOPMENT OF INNOVATIVE ENTREPRENEURSHIP ECOSYSTEMS IN ENTROPIC CONDITIONS

Purpose. Development and justification of an improved three-cluster GSI-model (Generation, Support, Implementation) ecosystem of innovative entrepreneurship in order to forecast its development under entropic conditions.

Methodology. The study used a mixed approach, which includes an analysis of literary sources to identify key factors of innovative entrepreneurship, construction of a 20-factor parametric model and assessment of its modifications in the context of the three-cluster GSI-model, scenario analysis (optimistic, several realistic options and pessimistic) with forecasting changes for 2026–2030, taxonomic analysis to calculate the integral development coefficient d_i, as well as verification of results by extrapolation of trends and comparative analysis taking into account international experience.

Findings. A three-cluster GSI-model (Generation, Support, Implementation) of the innovative entrepreneurship ecosystem has been developed. The scenario analysis (optimistic, realistic and pessimistic) conducted confirmed its effectiveness for the development of this ecosystem in Ukraine.

Originality. The proposed three-cluster GSI-model of the innovative entrepreneurship ecosystem integrates the activities of universities, scientific institutions, businesses, investors and government bodies. Unlike traditional approaches, this model offers comprehensive assessment of the processes of generating, supporting and implementing innovations in conditions of uncertainty.

Practical value. The introduction of the three-cluster GSI-model increases business innovation activity, strengthens the interaction of universities, research institutions, accelerators and venture funds with the authorities, accelerates the commercialization of innovations and increases the number of startups, which generally strengthens the competitiveness of the Ukrainian economy.

Keywords: *innovative entrepreneurship, ecosystem, entropy, development, business processes, parametric model, strategy*

Received: 31 January 2026
Accepted: 12 June 2026
Available online: 27 August 2026

Introduction. In the modern entropic environment, there is a technological strengthening, total digitalization and glocalization of markets and increased international competition, which create new opportunities and at the same time challenges for economies that seek to integrate into the world space on the basis of a knowledge-based economy. In accordance with modern entropic trends, it is innovative entrepreneurship that acts as a driving force for the development of scientific and technological potential and one of the main sources of stabilization of the national economy, which is extremely important for post-war recovery. At the same time, it is worth emphasizing that it stimulates the creation of new products, services and processes that are able to open additional niches in the domestic and foreign markets and, thus, contribute to increasing the competitiveness of the state in the global economic system. Given the key role of innovative entrepreneurship in the formation of sustainable economic growth, there is an ur-

© Riepina I., Tepliuk M., Shkoda T., Yakusheva N., Nemashkalo K., Onyshchenko V., 2026

gent need to create effective mechanisms to support and stimulate innovation processes. In Ukraine, despite significant scientific and technological potential, there are a number of unresolved problems that complicate the formation of a comprehensive system for the development of innovations:

1. Unstable and insufficient funding for research and development (R&D). Limited amounts of public and private funding do not allow universities and research organizations to fully realize the potential of fundamental and applied research.

2. Imperfect support infrastructure (business accelerators, innovation parks, technoparks, etc.). The low density of such structures hinders effective cooperation between business, science and state institutions.

3. High risks for investors and a weak legislative framework. The imperfect legal framework, the lack of transparent mechanisms for protecting intellectual property rights and tax obstacles complicate the process of attracting foreign direct and venture investments in national startups.

4. Low level of entrepreneurial and innovation culture. Insufficient attention to the development of innovation and entrepreneurship competencies in educational institutions leads to a shortage of qualified specialists capable of successfully developing and commercializing new ideas.

In entropic conditions and with the growing role of knowledge and technology, the development and implementation of an ecosystem model of innovative entrepreneurship is of particular relevance; this model will be able to unite the efforts of all stakeholders: from universities and scientific institutions to venture funds, corporations and government agencies. That is why the three-cluster GSI-model (Generation – Support – Implementation) is a comprehensive strategic approach that allows you to cover the key stages of innovation activity and ensure:

1. Generation of innovative ideas with the participation of educational and scientific organizations, the private sector and individual startups.

2. Systemic support through business accelerators, clusters, venture funds, state and public institutions that create conditions for the accelerated growth of innovative projects.

3. Effective implementation and commercialization of innovations, access to international markets and the formation of a positive investment environment.

The relevance of the study is enhanced by the need to create a favorable institutional environment for the development of entrepreneurship in entropic conditions, as well as global challenges and possible crisis phenomena. An increase in the number of successful innovative firms, startups, spinoffs and spinout companies directly affects the structural restructuring of the economy, increases the level of employment and creates the prerequisites for the creation of products with high added value, which in turn will contribute to increasing competitiveness. It has been proven that countries with a developed innovation sphere demonstrate higher rates of economic growth and adapt faster to dynamic changes in global markets, which emphasizes the relevance of the study for the economy of Ukraine.

That is why, we add that the development and implementation of the three-cluster GSI-model is an extremely urgent task for Ukraine. It will contribute to the formation of a holistic ecosystem in which the processes of creating innovative ideas, their support, financing and implementation are synchronized, which will generally allow increasing the international competitiveness of the national economy and lay the foundation for sustainable innovative development of the state.

Literature review. Modern research published in leading scientific publications demonstrates the multidimensional nature of innovative entrepreneurship and the need for a comprehensive approach to its development. One of the fundamental theoretical approaches remains the Triple Helix model proposed by A. Brem and A. Radziwon, which emphasizes the cooperation of three key actors: universities, business and government [1]. Drawing on the works by A. Brem and A. Radzivon, who analyzed the revolution in innovation systems, they emphasize and justify the need to achieve synergy within the 'Triple Helix' model for the development and implementation of local niche innovation projects, stressing that interaction between universities, industry and government creates a dynamic network that fosters the development of knowledge and innovation. In other words, it is precisely through tripartite partnerships that it is possible to establish a new scientific paradigm, foster the development of a knowledge-based economy and facilitate its subsequent commercialization.

This model reflects the transition from traditional national innovation systems to more integrated and interdependent relationships between the main actors of the innovation process.

The further evolution of this concept in the format of the "Quadruple Helix" and "Quintuple Helix" complements it with social and environmental components, recognizing the influence of society and the ecosystem environment on innovation processes. In their study, J. König, L. Suvala and C. Delargi consider the development of spiral models of innovation and sustainable development through the concepts of the "Triple Helix" and the Quadruple Helix, expanding previous models of knowledge creation that assume a pluralistic, co-evolutionary system that combines academic, market and social knowledge [2]. The system is fractal, that is, it is self-organizing and can function at different levels. The authors also complement the Triple Helix model (interaction between universities, industry and government) with a fourth element – civil society and culturally oriented aspects, which takes into account the role of democracy, media, creativity and social structures in the innovation process. Innovation, in their view, arises in dynamic, nonlinear systems, where different actors interact within an adaptive environment, and the Triple Helix supports the idea of flexible, open innovation that can adapt to change.

We consider this study to be the basis for further research on the interaction between knowledge, democracy and innovation, as well as the development of the Quintuple Helix concept, which takes into account environmental challenges and sustainability. E. Karayannis and D. Campbell explore the relationship between democracy, climate and the Quadruple Helix and Quintuple Helix innovation systems [3]. The authors emphasize that sustainable development and effective innovation ecosystems are possible only under conditions of

democratic governance and environmental responsibility. The main idea of their scientific research lies in two key concepts: "climate democracy" and "climate for democracy". The first emphasizes the need to create a democratic environment for the development of knowledge, technology and innovation, since without democratic institutions the potential for innovation is significantly limited. The second concept argues that environmental responsibility and sustainable development contribute to the strengthening of democratic structures, since effective solutions to environmental challenges require openness, public involvement and an inclusive approach. The authors view the Quadruple Helix as the interaction of science, industry, government and civil society, and the Five-Helix as an extension of this model, which includes the natural environment as an active factor in the innovation process. They argue that for innovation systems of the *21st* century, not only technological growth is important, but also the integration of socio-cultural and environmental aspects, since environmental challenges can become drivers of further development of knowledge and innovation. The authors' research makes an important contribution to the development of innovation theory, emphasizing the need for the relationship between democracy, innovation policy and environmental sustainability.

An important component of the development of innovative entrepreneurship is the interaction of scientific institutions and universities with business accelerators and venture funds. S. Mian, W. Lamin and A. Fayol analyze the current state of research in the field of technological business incubation (TBI), determining its role in supporting startups through financing, mentoring, networking opportunities and innovation infrastructure [4]. The authors consider the evolution of incubators, classify them into public, corporate, university and private, and also assess their impact on the success of startups. They note that incubators contribute to the survival and growth of companies, but there is little research on their long-term effect. The need for further research to improve incubator management strategies in a changing technological environment was proven by J. Block, M. Colombo, D. Cumming and S. Wismara. The researchers analyze current changes in the field of entrepreneurial financing, focusing on the emergence of new participants and instruments. They compare these new players along four dimensions: debt or equity financing, investment objective, investment approach, and investment target, and outline the factors that contributed to the emergence of these new players, dividing them into demand and supply factors [5]. Authors W. Drover, L. Busenitz, S. Matusik, D. Townsend, A. Anglin, and G. Dusnitsky analyze the current state of research in the field of entrepreneurial equity financing [6]. They focus on five main sources of financing: venture capital, corporate venture capital, business angel investments, crowdfunding, and accelerators. The research emphasizes that a high-quality innovation ecosystem should be not only scientific and applied, but also aimed at the commercialization of projects. In this regard, special attention is paid to academic entrepreneurship, in particular the emergence of spin-offs and spin-out companies that arise as a result of cooperation between teachers and researchers with business. D. Prokop examines how the configurations of university entrepreneurial ecosystems (UEs) influence the creation and success of spin-off companies [7]. The study shows that the effectiveness of UEEs depends on the level of connectivity and filtering processes that are shaped by spatial and organizational factors. The most successful ecosystems are characterized by strong network ties and optimal selection of spin-offs, which contributes to their long-term survival and growth. Such companies often become a catalyst for the growth of the innovation environment by attracting external investment and creating high-tech jobs. M. Guerrero and D. Urbano analyze the role of entrepreneurial universities in the development of innovation and entrepreneurship [8]. They consider how universities contribute to the creation of entrepreneurial ecosystems through educational programs, commercialization of knowledge, support for startups, and cooperation with business. The authors propose a research program that focuses on the mechanisms, policies, and institutional conditions that determine the effectiveness of entrepreneurial universities, as well as their impact on economic development.

A separate area of scientific research is the study of the role of infrastructure support and government regulation mechanisms. According to the results of a number of studies, the presence of a favorable legal framework, clearly formulated tax benefits, and transparent financial instruments directly affects the scaling of innovative projects and determines the ability of a country to successfully compete in the global environment. S. Klein and F. Pereira consider the entrepreneurial university, its concept, and the evolution of theoretical models [9]. Many academics focus on the institutional, economic and political factors that influence the transformation of higher education institutions into centers of entrepreneurship and innovation. At the same time, it is worth emphasizing that the regional context plays a key role in shaping their entrepreneurial culture, and the success of such initiatives depends on support from the government, the business sector and the academic community.

Government programs aimed at stimulating scientific developments are becoming drivers for the creation of new high-tech companies and attracting venture capital. Continuing this trend, N. Zayed, I. Mohamed, K. Islam, I. Perevozova, V. Nitsenko, O. Morozova analyze the emergence of new financial instruments, such as crowdfunding, business angels, corporate venture capital and accelerators [5]. The authors examine the reasons for these changes, in particular technological innovations, regulatory changes and the need for more flexible financing of startups. They emphasize that new financing mechanisms create both opportunities and challenges for the country's entrepreneurial ecosystem.

Along with this, numerous researchers emphasize the role of human capital and the corresponding entrepreneurial culture. The development of startup incubators, hackathons and startup competitions, as well as the availability of educational programs in entrepreneurship and innovation plays a crucial role in forming a critical mass of young entrepreneurs capable of proposing and implementing new ideas [1]. Entrepreneurial activity in modern innovation ecosystems also depends on the level of network interaction between stakeholders, since it is networks that provide knowledge dissemination, ac-

cess to resources and reduction of transaction costs. Of interest is the study by T. Nguyen, D. Nguyen, and V. Huynh, who demonstrated how entrepreneurship education affects students' intentions to engage in social entrepreneurship through individual capital (social, cultural, human) [10]. A study in Vietnam showed that social and cultural capital mediate this relationship, while human capital does not have a significant effect. The study highlights the importance of developing social and cultural capital in entrepreneurship education.

Bendig D., Goethe V., Eckardt D., and Schultz C. investigate the impact of the professional experience of corporate venture capital (CVC) leaders on the innovation performance of parent companies. Using data from various sources, they find that different aspects of CVC leader experience have different effects on parent companies' innovation performance. In particular, venture capital and entrepreneurship experience are associated with increased innovation performance, while excessive corporate experience may limit this effect. The study highlights the importance of carefully selecting CVC leaders to achieve optimal innovation performance [11].

Ukrainian scholars are also actively studying the problems of innovative entrepreneurship, while developing conceptual frameworks for the formation of relevant ecosystems. Researchers H. Chernoivanova, T. Lepeyko, S. Vasylyk, K. Nemashkalo, and O. Nechyporuk analyze the process of transforming ideas into breakthrough innovations [12]. They record the key stages of this process, including generation of ideas, their evaluation, development and market introduction. The authors emphasize the importance of creating a favorable environment for innovation, which includes support from management, the availability of resources and a culture that encourages creativity and risk. They also consider barriers that may hinder the successful transformation of ideas, such as organizational inertia, insufficient funding and resistance to change. S. Salman, S. Poddar, and V. Nitsenko analyze the possibilities of commercializing high-tech developments through close collaboration between universities and the business sector, which creates the prerequisites for large-scale technology transfer. Researchers note the importance of state programs aimed at stimulating R&D and the formation of venture infrastructure [13]. At the same time, Starostina A., Bugrov V., Kravchenko V., Gatto G., Kochkina N. analyze the development of entrepreneurial universities in Ukraine during the war [14]. The authors explore the mechanisms of their work, identify clusters of the most entrepreneurially oriented educational institutions and highlight key challenges, in particular the lack of cooperation with business and funding. They offer strategic approaches for the adaptation of universities in crisis conditions and the post-war period.

Khan S., Zayed N., Darwish S., Nitsenko N., Islam K., Hassan Md., Dubrova O. investigate innovative approaches to the formation of business models of universities in the socio-economic space dependent on COVID-19 [15]. In their works, these researchers analyze the impact of the pandemic on the business environment and propose adaptation strategies to ensure the sustainable development of universities in conditions of entropy. In other words, each study makes an important contribution to the field of innovative universities, as it emphasizes the need to adapt business models to the new realities brought about by the pandemic and demonstrates how innovative approaches can contribute to the sustainable development of universities in conditions of entropy. Other authors largely focus on forecasting development through innovative solutions [16, 17].

In general, world practice emphasizes the need for a comprehensive approach to the development of innovative entrepreneurship, which includes close integration of education, science and business, an extensive network of infrastructure support, public and private financing, as well as a sustainable orientation towards the commercialization of research and development (R&D) results [18, 19]. In this context, the three-cluster GSI-model logically agrees with the recommendations of researchers on the synergistic combination of innovation generation processes, their comprehensive support and subsequent commercialization. Its implementation is potentially capable of reducing the gap between theoretical developments and real market implementation, thus ensuring the accelerated development of national innovative entrepreneurship in the context of globalization.

Working hypothesis. It is believed that the implementation of the three-cluster GSI-model (Generation – Support – Implementation) in the context of a sound state policy and appropriate infrastructure support will form synergistic relationships between scientific and educational institutions, enterprises, venture funds and investors, which will contribute to the growth of innovative activity, an increase in the number of startups, an increase in the level of commercialization of scientific developments and, as a result, an increase in the competitiveness of the domestic economy in the global market.

Proposal. In conditions of limited resources, weak interaction between science and business, imperfect legislative framework and high risks for investors, the task is to develop an effective model of the ecosystem of innovative entrepreneurship, which will contribute to attracting the necessary resources, commercialization of innovations and entry of enterprises into global markets. The answer to these challenges is provided by the three-cluster GSI-model (Generation – Support – Implementation), which covers three key areas: generation of business ideas, comprehensive support for their development and scaling, as well as implementation and commercialization of innovations.

The purpose of this study is to develop a three-cluster GSI-model ecosystem of innovative entrepreneurship in conditions of entropic development, capable of ensuring the transition to an innovative model of the economy through balanced interaction of all subjects of the ecosystem. The practical implementation of such a model will become the basis for building an effective innovation management system, stimulate investment attraction, increase the level of knowledge-intensiveness of the national economy and promote the integration of domestic enterprises into world markets.

Methodology. In the process of research, a systematic approach was used to identify key components of the ecosystem of innovative entrepreneurship and establish relationships between them; parametric modeling and factor analysis, which allowed forming a 20-factor model and assessing the impact of each factor on the dynamics of innovative development; scenario approach

and forecasting methods (optimistic, realistic, pessimistic scenarios), which made it possible to determine possible trajectories of the development of innovative entrepreneurship; taxonomic analysis for an integral assessment of the state and degree of changes in the three-cluster GSI-model; statistical and economic and mathematical methods, which ensured the processing of empirical data and the identification of patterns in the formation of the ecosystem of innovative entrepreneurship in Ukraine.

Findings. In the current entropic conditions of the market environment, innovative entrepreneurship in Ukraine is developing effectively, but the prospects for entering the international market for our enterprises are almost impossible, since it has low barriers in the context of globalization [20, 21]. That is why we consider it necessary to form an effective ecosystem model. We propose for implementation a three-cluster GSI-model, which includes: cluster G (generation) – generation of innovative business ideas, cluster S (support) – support for the development and functioning of innovative entrepreneurship, as well as cluster I (implementation) – implementation of innovative ideas and solutions.

The development of innovative entrepreneurship in Ukraine requires comprehensive support, acceleration and scaling. Important prerequisites for the transformation of the outlined sphere are the formation of an entrepreneurial culture, the development of innovative and business education, strengthening of the role of science and high-tech sectors of the economy, which motivates key players. Investments in research and development (R&D) are of key importance, as they determine the competitiveness of the country in the global market. At the same time, digital transformation creates the basis for the rapid growth of innovative activity, which in turn ensures competitiveness. State funding, especially support for startups at the early stages and the introduction of risk reduction mechanisms for investors, will contribute to the emergence of new projects and their scaling, which leads to proactive development. An equally important factor is investment in human capital, as it determines the level of innovative activity of society.

In the field of innovative entrepreneurship, a special role is played by high-quality information support at different stages of the innovation cycle, especially when the market environment is in a state of entropy. At the same time, it is the automation of processes in Ukraine that opens up opportunities for effective analysis of innovation projects, search for partners, creation and support of business plans, risk forecasting and monitoring of data from various sources. Accordingly, permanent collection and processing of information becomes one of the key tasks for innovative companies, where automated solutions significantly accelerate this process and increase the effectiveness of activities, ensuring the competitiveness of market players, which creates the prerequisites for the sustainable development of innovative companies in the country. Considering the above, a three-cluster GSI model is proposed, which can become a new paradigm for the functioning of innovative entrepreneurship in Ukraine. Its implementation will allow increasing the efficiency of innovation processes and strengthening the country's competitive position in world markets. The development of an improved ecosystem model involves a number of measures that will positively impact each of the clusters.

Cluster G (generation) is aimed at stimulating innovative activity in universities, institutions of the National Academy of Sciences of Ukraine and among individual scientists. Its task is to create a favorable environment for the formation and implementation of new ideas. The implementation of measures within this cluster will help to improve the quality of education and the training of highly qualified personnel, which in turn will foster the development of an entrepreneurial and innovative culture within society, as well as increasing the number of start-ups and spin-off and spin-out companies. The implementation of initiatives within this cluster will allow for more active attraction of investments, expanding financing opportunities for innovative entrepreneurship, increasing the number of implemented projects and created jobs.

Cluster I (implementation) focuses on the implementation and commercialization of innovative solutions. It ensures cooperation between startups and innovative companies that can evolve into Spin-off or Spin-out structures, creating new products and technologies. The expected result of the implementation of this cluster is an increase in the number of startups, more active attraction of investments and acceleration of the entry of innovative ideas into the market [1, 22]. The proposed three-cluster GSI-model creates conditions for the balanced functioning of the ecosystem of innovative entrepreneurship, which will ensure its sustainable development and will become the basis for the country's transition to an innovative model of the economy. The transition to an improved model of the ecosystem of innovative entrepreneurship will ensure its effectiveness, and forecasting the development of this system will make it possible to determine the main trends of economic growth, assess possible future scenarios and choose the optimal ways and timing of their implementation. It is proposed to forecast the development and functioning of the improved model according to three scenarios: optimistic, realistic and pessimistic (Table 1).

In the case of the implementation of the optimistic scenario, changes will occur in all three clusters of the GSI-model, which will lead to the transformation of all 20 factors of the parametric model ($\Delta GSI = 3/3$). This means that all measures will be successfully implemented, and KPIs will reach the planned values. Table 1 highlights the factors X1–X20 that will undergo changes. It can therefore be argued that these include:

- an increase in the number of organizations carrying out scientific research and development;
- a rise in the proportion of enterprises engaged in innovation;
- the development of venture capital funds; an increase in expenditure on fundamental and applied research, as well as on scientific and technical development;
- a rise in the scientific intensity of GDP;
- an increase in the implementation of innovative projects;
- an increase in the number of registered patents, etc.

It is forecast that the share of innovative products will increase, and Ukraine's rankings in the 'Doing Business' and 'Global Innovation Index' will improve.

Table 1

Forecast development of the innovative entrepreneurship ecosystem model in entropic conditions for 2026–2030

Factor	Optimistic scenario	Realistic scenario 2 Δ*GS*	Realistic scenario 3 Δ*SI*	Realistic scenario 3 Δ*SI*	Realistic scenario 5 Δ*G*	Realistic scenario 6 Δ*S*	Realistic scenario 7 Δ*I*
X1	1,000	1,000	–	1,000	1,000	–	–
X2	17	17	–	17	17	–	–
X3	18	–	18	18	–		18
X4	350	350	350	–	–	350	–
X5	5,868	5868	5868	–	–	5,868	–
X6	4,315	4315	4315	–	–	4,315	–
X7	14,877	14,877	14,877	–	–	1,4877	–
X8	0.55	0.55	0.55	–	–	0.55	–
X9	360	–	360	360	–		360
X10	3,000	3000	3000	–	–	3,000	–
X11	5,500	5500	5500	–	–	5,500	–
X12	2,700	2700	2700	–	–	2,700	–
X13	26,000	26,000	26,000	–	–	26,000	–
X14	22,400	–	22,400	22,400	–	–	22,400
X15	1,850	–	1,850	1,850	–	–	1,850
X16	700	–	700	700	–	–	700
X17	553	–	553	553	–	–	553
X18	2	–	2	2	–	–	2
X19	58	–	58	58	–	–	58
X20	40	–	40	40	–	–	40

As a result, under the optimistic scenario, the development of the innovative entrepreneurship ecosystem will contribute to increasing the efficiency of generating innovative ideas, supporting the ecosystem and successfully implementing developments, which will ensure the commercialization of innovations and profit.

Realistic scenario (2 Δ*GS*, 2025–2029). Unlike the optimistic scenario, the realistic scenario assumes changes in only two of the three clusters (Δ*GS* = 2/3). This means that the planned KPIs will be achieved partially – only in the GS clusters.

In other words, the result may be that 11 of the model's 20 factors – X1, X2, X4–X8, X10–X13 – lead to an expected increase in the number of organizations carrying out research and development, which in turn will help to boost the country's overall innovation potential. Thus, changes under the realistic scenario will cover 11 out of 20 factors, which will positively affect the development of innovative entrepreneurship in Ukraine. The growth of indicators in the field of generation of innovative ideas and support for entrepreneurship will become an important basis for the further effective implementation of innovations and their commercialization. The development of the model of the ecosystem of innovative entrepreneurship when implementing the realistic scenario 3 Δ*SI* for 2026–2030 involves changes in *SI* lusters.

The implementation of this scenario involves partial changes to the GSI model due to the transformation of *SI* clusters (Δ*SI* = 2/3). This means that the planned KPIs will be achieved only within these clusters. As a result, 18 out of 20 factors of the parametric model (X3–X20) will change. Among the expected results are an increase in the share of enterprises that will implement innovations; an increase in the number of venture funds; an increase in the volume of financing for fundamental and applied scientific research, as well as scientific and technical (experimental) developments; an increase in the level of knowledge-intensiveness of GDP; an intensification of the implementation of innovative projects; an increase in the number of registered patents for inventions, utility models, industrial designs and trademarks. In addition, new technological processes, innovative products, resource-saving and low-waste technologies and new types of equipment will be introduced; the share of implemented innovative products in industrial production will increase, and Ukraine's positions in the Doing Business and Global Innovation Index rankings will improve.

Thus, the implementation of 18 out of 20 changes will contribute to a significant increase in support for innovative entrepreneurship, more effective implementation of developments, faster commercialization of innovations and profit.

Realistic scenario 4 (ΔGI, 2025–2029).

This scenario assumes changes in the *GI* clusters, while the S cluster will remain without transformations (Δ*GI* = 2/3). Thus, the planned KPI will be achieved only within the GI clusters.

In total, 11 changes will occur out of 20 factors of the parametric model (X1–X3, X9, X14–X20). The following is expected: an increase in the number of organizations that will carry out scientific research and development; an increase in the proportion of enterprises engaged in and implementing innovations; implementation of innovative projects; introduction of new technological processes, innovative types of products, low-waste and resource-saving technologies, as well as new types of equipment. In addition, the share of sold innovative products in the structure of industrial production will increase and Ukraine's position in the Doing Business and Global Innovation Index rankings will improve.

Thus, changes under scenario 4 (11/20 factors) will contribute to enhancing the generation of innovative ideas, increasing the innovative activity of enterprises and improving the processes of commercialization of innovations.

Let us consider partial changes in the *GSI* model of the realistic scenario when implementing measures of one cluster, that is, the forecast of the development of the innovative entrepreneurship ecosystem model in Ukraine when implementing the realistic scenario 5 ΔG for 2026–2030.

The calculated forecast modified coefficient of innovative entrepreneurship development d_i for 2025–2029 under different scenarios makes it possible to predict the development of innovative entrepreneurship in Ukraine when implementing the proposed measures and changes in the relevant clusters of the GSI model of the innovative entrepreneurship ecosystem. The summarized data of the calculations are presented in Table 2.

In 2026–2030, the development of innovative entrepreneurship in Ukraine can take different paths. The optimistic scenario means rapid growth and reaching a new level in the global economy. Realistic scenarios involve moderate, but still positive growth, albeit with certain fluctuations. The pessimistic option is practically no change, movement according to the old inertia. Therefore, it is obvious that a breakthrough requires specific reforms and bold steps that will give impetus not only to business, but also to the economy of Ukraine as a whole.

Conclusions. The study substantiated that the three-cluster GSI-model (Generation – Support – Implementation) is an effective mechanism for the systemic development of innovative entrepreneurship in Ukraine. Its uniqueness lies in the simultaneous coverage of three key components:

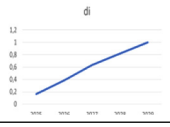
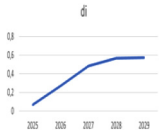
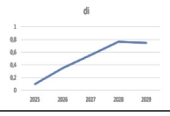
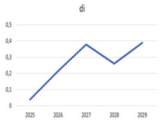
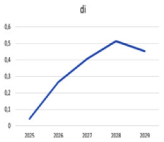
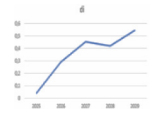
1. Generation – provides not only for an increase in the amount of scientific research and development, but also for the development of academic entrepreneurship, stimulating the creation of educational programs on innovation and entrepreneurship, and establishing effective technology transfer.
2. Support – the cluster is designed to create a favorable regulatory environment and appropriate incentives for attracting investments, increasing the knowledge-intensiveness of GDP and activating patent activity.
3. Implementation – effective commercialization of innovations and scaling of innovative projects. Cluster I focuses on accelerating the market entry of new developments and technologies, attracting additional resources and investments for the rapid growth of projects.

Based on the 20-factor parametric model and scenario approach (optimistic, realistic variations and pessimistic scenarios), it was established that:

1. Under the optimistic scenario ΔGSI (simultaneous improvement of clusters *G*, *S* and *I*), the greatest

Table 2

Change in the d_i, coefficient and trend when implementing different scenarios for 2026–2030

Scenario	Changes	d_i					Trend
		2026	2027	2028	2029	2030	
1	ΔGSI	0.161	0.383	0.635	0.818	1	
2	ΔGS	0.068	0.269	0.483	0.567	0.573	
3	ΔSI	0.099	0.353	0.557	0.765	0.747	
4	ΔGI	0.077	0.302	0.53	0.48	0.677	
5	ΔG	0.038	0.214	0.378	0.261	0.389	
6	ΔS	0.043	0.264	0.406	0.514	0.452	
7	ΔI	0.04	0.291	0.453	0.42	0.545	

synergy and the highest growth rates of the coefficient of development of innovative entrepreneurship (d_i) are observed. This confirms the need for comprehensive reform of all components of the ecosystem.

2. Realistic scenarios ΔGS, ΔSI, ΔGI, ΔG, ΔS, ΔI demonstrate a positive, but less dynamic growth trend. At the same time, each of the strategies of "partial changes" covers either two or only one cluster. Although such approaches contribute to the gradual improvement of the innovation environment, the maximum effect can be achieved only if all three components are simultaneously synchronized.

3. The pessimistic scenario assumes the absence of any qualitative reforms or support measures, which actually preserves the current state of innovative entrepreneurship based on the trend forecast, without a significant improvement in key indicators (number of startups, patent activity, venture financing, etc.).

The practical significance of the results lies in the possibility of using the proposed three-cluster GSI-model by government authorities, the business community, educational and research institutions, as well as public and international organizations in the formation of strategic priorities and programs to support innovation. In particular, the implementation of the proposed measures within each cluster will contribute to:

- increasing the level of knowledge-intensiveness of GDP and the growth rates of sectors with high added value;

- increasing the number of startups, spin-offs and spin-outs and increasing the overall innovation level of enterprises;

- strengthening the infrastructure (accelerators, venture funds, business incubators, etc.) and creating favorable financial conditions for the development of innovations.

In general, the three-cluster model acts as a strategic systemic tool that enables a comprehensive approach to the development of innovative entrepreneurship, harmonizing the interests and resources of all stakeholders. Its phased implementation will ensure higher adaptability of the Ukrainian economy to global challenges, stimulate the formation of knowledge-intensive industries, and open up new opportunities for international cooperation and attracting investments in high-tech sectors.

Competition for grants of the President of Ukraine to support scientific research and development for doctoral students "Entropic development of the logistics system of agro-trading in Ukraine under conditions of transcendence" No. 2025.04/000.

References.

1. Brem, A., & Radziwon, A. (2017). Efficient Triple Helix collaboration fostering local niche innovation projects – A case from Denmark. *Technological Forecasting and Social Change*, *123*, 130-141. https://doi.org/10.1016/j.techfore.2017.01.002

2. König, J., Suwala, L., & Delargy, C. (2020). Helix Models of Innovation and Sustainable Development Goals. In Leal Filho, W., Azul, A., Brandli, L., Lange Salvia, A., & Wall T. (Eds.). *Industry, Innovation and Infrastructure. Encyclopedia of the UN Sustainable Development Goals*. Springer, Cham. https://doi.org/10.1007/978-3-319-71059-4_91-1

3. Carayannis, E. G., & Campbell, D. F. J. (2021). Democracy of climate and climate for democracy: The evolution of Quadruple and Quintuple Helix innovation systems. *Journal of the Knowledge Economy, 12*(4), 2050-2082. https://link.springer.com/article/10.1007/s13132-021-00778-x

4. Mian, S., Lamine, W., & Fayolle, A. (2016). Technology business incubation: An overview of the state of knowledge. *Technovation, 50-51*, 1-12. https://doi.org/10.1016/j.technovation.2016.02.005

5. Block, J. H., Colombo, M. G., Cumming, D. J., & Vismara, S. (2018). New players in entrepreneurial finance and why they are there. *Small Business Economics, 50*(2), 239-250. https://link.springer.com/article/10.1007/s11187-016-9826-6

6. Drover, W., Busenitz, L., Matusik, S., Townsend, D., Anglin, A., & Dushnitsky, G. (2017). A review and road map of entrepreneurial equity financing research: Venture capital, corporate venture capital, angel investment, crowdfunding, and accelerators. *Journal of Management, 43*(6), 1820-1853. https://doi.org/10.1177/0149206317690584

7. Prokop, D. (2021). University entrepreneurial ecosystems and spinoff companies: Configurations, developments, and outcomes. *Technovation, 107*, 102286. https://doi.org/10.1016/j.technovation.2021.102286

8. Guerrero, M., & Urbano, D. (2019). A research agenda for entrepreneurship and innovation: The role of entrepreneurial universities. In D. B. Audretsch, E. E. Lehmann, & A. N. Link (Eds.). *A research agenda for entrepreneurship and innovation*, (pp. 107-133). Edward Elgar Publishing. https://doi.org/10.4337/9781788116015.00012

9. Klein, S. B., & Pereira, F. C. M. (2020). Entrepreneurial university: conceptions and evolution of theoretical models. *Universidade Federal Fluminense*, *14*(4), 20-35. https://doi.org/10.12712/rpca.v14i4.43186

10. Nguyen, T. T. D., Nguyen, D. T., & Huynh, V. A. (2024). The mediating effect of individual capital in the relationship between entrepreneurship education and social entrepreneurship intentions. *International Journal of Educational Management, 38*(7), 2075-2093. https://doi.org/10.1108/IJEM-09-2023-0454

11. Bendig, D., Göttel, V., Eckardt, D., & Schulz, C. (2024). Human capital in corporate venture capital units and its relation to parent firms' innovative performance. *Research Policy, 53*(6), 105003. https://doi.org/10.1016/j.respol.2024.105003

12. Chernoivanova, H., Lepeyko, T., Vasylyk, S., Nemashkalo, K., & Nechyporuk, O. (2023). Conceptual principles of labor intensity determination for rationing of innovative work at the enterprise. *Financial and Credit Activity Problems of Theory and Practice*, *4*(51), 480-490. https://doi.org/10.55643/fcaptp.4.51.2023.4101

13. Salman, S.A., Poddar, S., & Nitsenko, V. (Eds.) (2023). *Recent Trends in Business and Entrepreneurial Ventures*. USA, Nova Science Publishers. https://doi.org/10.52305/KZZV1105

14. Starostina, A., Bugrov, V., Kravchenko, V., Gatto, G., & Kochkina, N. (2023). Entrepreneurial university: Exploring its essence, phases of development, and operating mechanism during wartime in Ukraine. *International Journal of Educational Development*, *103*, 102895. https://doi.org/10.1016/j.ijedudev.2023.102895

15. Khan, S., Zayed, N. M., Darwish, S., Nitsenko, N., Islam, K. M. A., Hassan, Md. A., & Dubrova, O. (2023). Pre and Present COVID-19 Situation: A Framework of Educational Transformation in South Asia Region. *Emerging Science Journal*, *7*(Special Issue "COVID-19: Emerging Research"), 81-94. https://doi.org/10.28991/ESJ-2023-SPER-06

16. Andriushchenko, K., Kovtun, V., Cherniaieva, O., Datsii, N., Aleinikova, O., & Mykolaiets, A. (2020). Transformation of the Educational Ecosystem in the Singularity Environment. *International Journal of Learning, Teaching and Educational Research*, *19*(9), 77-98. https://doi.org/10.26803/ijlter.19.9.5

17. Ingram, K., Diachenko, O., Halytskyi, O., Nitsenko, V., Romaniuk, M., & Zhumbei, M. (2022). Formalization of the Optimal Choice of the Activities of Agricultural Enterprises for the Implementation of Information and Communication Technologies. *Financial and Credit Activity: Problems of Theory and Practice*, *3*(44), 141-149. https://doi.org/10.55643/fcaptp.3.44.2022.3758

18. Onyshchenko, V., Zahorelska, T., & Klymenko, D. (2024). Using strategic analysis to assess the construction industry in Ukraine. *Economics and Region*, *1*(92), 26-32. https://doi.org/10.26906/EiR.2024.1(92).3305

19. Stamm, I., & Gutzeit, M. (2026). *The Innovative Capacity of Entrepreneurial Groups*. In: Schulz-Schaeffer, I., Windeler, A., Blättel-Mink, B. (Eds.). *Handbook of Innovation*. Springer, Cham. https://doi.org/10.1007/978-3-031-25143-6_60-1

20. Mia, M. M., Rizwan, S., Zayed, N. M., Nitsenko, V., Miroshnyk, O., Kryshtal, H., & Ostapenko, R. (2022). The Impact of Green Entrepreneurship on Social Change and Factors Influencing AMO Theory. *Systems*, *10*(5), 132. https://doi.org/10.3390/systems10050132

21. Suparna, G., Kot, M., Dacko-Pikiewicz, Z., Riana, I. G., Rihayana, I. G., & Arsha, I. M. R. M. (2024). Cultivating creativity: strategies for enhancing innovative behavior in small and medium enter-

prises. *Intellectual Economics*, *18*(2), 429-449. https://doi.org/10.13165/IE-24-18-2-09
22. Alici, A. (2025). Financial sustainability performance of airlines. *Scientific Journal of Silesian University of Technology. Series Transport*, *129*, 27-50. https://doi.org/10.20858/sjsutst.2025.129.2

Прогнозування розвитку екосистем інноваційного підприємництва в ентропійних умовах

І. Рєпіна[1], *М. Теплюк*[*1,2], *Т. Шкода*[1], *Н. Якушева*[1], *К. Немашкало*[3], *В. Онищенко*[4]

1 – Київський національний університет імені В. Гетьмана, м. Київ, Україна
2 – Фонд SCIRE, м. Варшава, Польща
3 – Харківський національний економічний університет імені Семена Кузнеця, м. Харків, Україна
4 – Навчально-науковий інститут «Придніпровська державна академія будівництва та архітектури», Український державний університет науки і технологій, м. Дніпро, Україна
* Автор-кореспондент e-mail: maria_6.11@kneu.edu.ua

Мета. Розробити трикластерну GSI-model (Generation, Support, Implementation) екосистеми інноваційного підприємництва для прогнозування її розвитку в ентропійних умовах.

Методика. У дослідженні застосовано змішаний підхід, що охоплює аналіз літературних джерел для визначення ключових чинників інноваційного підприємництва, побудову 20-факторної параметричної моделі й оцінку її модифікацій у контексті трикластерної GSI-model, сценарний аналіз (оптимістичний, кілька реалістичних варіантів і песимістичний) із прогнозуванням змін на 2026–2030 роки, таксономічний аналіз для розрахунку інтегрального коефіцієнта розвитку d_i, а також верифікацію результатів шляхом екстраполяції трендів і порівняльного аналізу з урахуванням міжнародного досвіду.

Результати. Розроблена трикластерна GSI-model (Generation, Support, Implementation) екосистеми інноваційного підприємництва. Проведений сценарний аналіз (оптимістичний, реалістичні й песимістичний), що підтвердив її ефективність для розвитку вказаної екосистеми в Україні.

Наукова новизна. Запропоновано трикластерну GSI-model екосистеми інноваційного підприємництва, що інтегрує взаємодію університетів, наукових установ, бізнесу, інвесторів і державних інституцій. На відміну від існуючих підходів, модель забезпечує комплексне оцінювання процесів генерації, підтримки та впровадження інновацій в умовах невизначеності.

Практична значимість. Запровадження трикластерної GSI-model підвищує інноваційну активність бізнесу, посилює взаємодію університетів, дослідних установ, акселераторів і венчурних фондів із владою, прискорює комерціалізацію інновацій і збільшує кількість стартапів, що загалом зміцнює конкурентоспроможність економіки України.

Ключові слова: *інноваційне підприємництво, екосистема, ентропія, розвиток, бізнес-процеси, параметрична модель, стратегія*