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Revista de Cercetare si Interventie Sociala

ISSN: 1583-3410 (print), ISSN: 1584-5397 (electronic)

STATE REGULATION AND INNOVATION INFRASTRUCTURE IN THE NATIONAL SYSTEM

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Revista de cercetare și intervenție socială, 2025, vol. 89, pp. 100-127

https://doi.org/10.33788/rcis.88.6

Published by:
Expert Projects Publishing House

expert projects
publishing

On behalf of:
„Alexandru Ioan Cuza" University,
Department of Sociology and Social Work
and
HoltIS Association

State Regulation and Innovation Infrastructure in the National System

Anastasiya ILYINA[1]

Abstract

The article examines the main problems that limit the effective functioning of the national innovation system. The low level of commercialization of scientific research is significantly affected by the weak interaction between state authorities and innovation institutions (in particular, scientific institutions, technopolises, technoparks, business incubators) and, as a result, insufficient state support for innovative enterprises. The study is based on the concept of multi-level development of the national innovation system, which involves the interaction of state institutions, the private sector, educational institutions, scientific organizations, and international cooperation. Human capital plays a key role in shaping the innovation environment, emphasizing the need to create favorable conditions for training highly qualified specialists and developing technological entrepreneurship. As an example, to determine the effectiveness of interaction between state authorities and innovation institutions in Ukraine, an analysis of the functioning of technoparks and their impact on the innovation activity of industrial enterprises was conducted. Changes in the legislation regulating the activities of technoparks, in particular the abolition of tax benefits, led to the practical termination of their activities, affecting the innovative development of industrial enterprises. Possible ways of restoring and developing technoparks are presented, in particular in the context of attracting additional sources of financing, developing public-private partnerships, attracting international investments, etc. The results of the study will be useful in shaping state policy on innovation development, improving mechanisms for interaction between state authorities and innovation institutions, and creating an effective model for the functioning of the national innovation system.

Keywords: national innovation system; innovation policy; state authorities; innovation institutions; public-private partnerships; technoparks; human capital; innovative economy.

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Introduction

The development of the latest technologies and national innovation systems (NIS) play an important role in ensuring economic growth, competitiveness of the state and improving the quality of life of the population. The formation of an effective national innovation system involves close cooperation between public authorities and innovation institutions, including research institutions, universities, technology parks and business structures.

The relevance of studying this issue is due to the need to improve the mechanisms of public administration of innovation activities, develop effective models of financing and stimulating innovation, and create a favorable regulatory environment for the development of knowledge-intensive business. In the context of digital transformation and increasing international competition, countries that do not have effective tools to support innovation risk losing their potential, which could lead to slower economic growth, intellectual capital outflow, and technological lag.

At the same time, sustainable development is the result of joint efforts of society aimed at achieving a balance between human progress and environmental protection. Society is constantly striving to maximize benefits with minimal resource expenditures, which encourages it to accumulate experience, introduce new technologies and improve institutional mechanisms. It is the combination of state support for innovation and the pursuit of sustainable development that creates the conditions for long-term economic growth, increased competitiveness, and the preservation of natural resources for future generations (Bojie Fu *et al.,* 2019).

The main problems that hinder the effectiveness of the national innovation system include insufficient funding for scientific and innovative ideas, and the level of public and private investment is much lower than in developed countries. The next problem is the weak interaction between business and science, with a lack of effective mechanisms for commercializing scientific developments and a low level of cooperation between universities and enterprises. Another problem is the outdated material and technical base and personnel outflow. For example, outdated regulations do not meet the requirements of modern society. Combined with staff turnover, this is a ticking time bomb that is slowly pushing the country backward. To the previously mentioned problems, we should add another one - the low level of digitalization and the introduction of high technologies. It is the lack of infrastructure to support startups and the lack of incentives to switch to modern digital solutions that is one of the main problems of the development of the state in the twenty-first century. In this context, the development and implementation of an effective national innovation policy is a very important task that contributes to sustainable development, increased economic productivity and strengthening the country's international position.

For Ukraine, as well as for most developing countries, sustainable development is a priority task, as it involves economic growth, social stability and environmental safety. With this in mind, the national innovation system plays a key role, as it is innovative technologies and effective management decisions that contribute to the formation of a balanced model of state development for the coming years. In this context, modern studies of socio-economic security focus on the integration of the concept with the principles of sustainable development. In particular, the importance of balancing economic interests, social justice, and environmental sustainability is considered (Felenchak *et al.,* 2024). Innovative activities in the field of sustainable development cover a number of aspects, in particular:

– green economy, which involves the development of environmentally friendly technologies, renewable energy, resource-saving production processes, etc;
– social innovations, which determine the creation of new mechanisms of social protection, affordable education, medical technologies and convenient digital services for the population;
– institutional innovations, which are determined by the reform of public administration to support innovation, create legal mechanisms to stimulate business and implement modernized solutions.

Investment and innovation play a key role in ensuring economic security. The more favorable the conditions for investors, the more money is invested in the economy, which contributes to its development. If the level of investment activity increases, the economy grows faster. If the number of innovations increases, the country gains competitive advantages in the global market. Thus, investment and innovation are interconnected and have a direct impact on economic growth (Prokopenko *et al.,* t ol 2019).

The interaction of public authorities and innovation institutions within the framework of sustainable development should be aimed at stimulating scientific research, developing public-private partnerships, and integrating environmental standards into all sectors of the economy. Gradually, national innovation systems are becoming the basis for the transition to a sustainable development model, ensuring the long-term competitiveness of the state at the international level.

The purpose of the article is to study the national innovation system as a set of relationships between public authorities and innovation institutions, to determine the mechanisms of their interaction, and to develop recommendations which have an impact on improving the efficiency of public administration in the field of innovation.

Thus, the article focuses on the analysis of the institutional framework for the functioning of the national innovation system, the role of public policy in stimulating innovation development, and the mechanisms for financing and regulating innovation processes. Special attention should be paid to the issues of public-private partnership, technology transfer and creation of a favorable innovation environment for the development of the State.

Literature Review

Today, many Ukrainian and foreign scholars are interested in studying the concept of a national innovation system that develops under the influence of the accumulation and modernization of human capital. Ivanova (2024) focuses her research on the legislative support of the national innovation system in the context of martial law and the global economic crisis. The article establishes that despite the significant amount of regulations governing the innovation sphere, there is currently no systemic unity in these regulations, which is often fragmented, and thus complicates the implementation of innovative ideas and limits their full development in society.

Vysotsky (2023) made a step forward in studying the concept and structure of the national innovation system. The work focused on analyzing the main approaches to defining the concept of the national innovation system. The study found that within the framework of economic theory, the national innovation system is considered in three main aspects: as a set of institutions engaged in the creation and dissemination of innovations; as an interconnected set of economic mechanisms and activities that contribute to the implementation of innovation processes; as a component of the national economy that integrates innovation processes into the sustainable development of the economy and society. The national innovation system includes economically, organizationally and legally interacting entities, including participants in scientific and innovation activities, infrastructure and public authorities. The activities of innovation entities are aimed at active participation in the development of innovations and their support. The system's activities are focused on conducting research and developing tools that are used in various sectors of the economy and the social sphere.

Khimenko (2020), in the process of studying the principles and ways to improve the state policy to enhance the development of the national innovation system in Ukraine, indicates that the issues of formation and development of the national innovation system, capable of ensuring the creation and supply of high-tech products to the international market by national producers, as well as increasing the country's competitiveness and, as a result, improving the quality of life of its citizens, remain an important topic of professional discussions and scientific research in Ukraine.

Sytnyk *et al.* (2022) determine that the innovative development of any state is to some extent ensured by financial, economic and technological aspects. Innovative development itself is turbulent due to the nonlinear nature of its management. The study found that the introduction of approaches that would allow overcoming the institutional weakness of the state is a driving force in innovative development. At the same time, political technologies can influence the formation of development priorities by using different approaches to managing public opinion. Their nonlinear dynamics requires periodic review of goals, methods and approaches in

the activities of the authorities, as well as ensuring a balance between the political and administrative components of governance.

Mykhaylova *et al.* (2023) consider the development of green energy as a key factor in Ukraine's energy independence. The authors identify the most popular types of green energy sources and provide examples of their application in Ukraine. A separate opinion is expressed on the effectiveness of using green energy sources under martial law and post-war reconstruction. For our research, the article is useful because it helps to establish a link between innovative resources and types of green energy as a factor contributing to the development of the state and its innovative capabilities.

Bojie Fu *et al.* (2019) believes that sustainable development can be viewed as the result of the joint activities of society aimed at achieving a balance between human progress and environmental preservation. As society seeks to maximize benefits with minimal resource expenditure, it is constantly gaining experience by developing technological innovations and implementing institutional changes. With this in mind, the authors divided the 17 Sustainable Development Goals (SDGs) into three main groups: basic needs, expected goals, and governance. This approach facilitates faster implementation of the strategy through effective distribution of tasks and cooperation between governing bodies (Cordova & Celone, 2019). Scientific and technological development helps to increase productivity and meet the basic needs of the population. At the same time, it makes it possible to provide more ecosystem services without exceeding the planet's natural capacity. For our research, the article is useful because it provides a deep understanding of the importance of sustainable development as a comprehensive goal that requires the integration of scientific, technical, and managerial approaches. In addition, it helps to define the roles of innovation and good governance in achieving a balance between economic growth and the preservation of environmental resources.

Flechas *et al.,* (2022) emphasize that current business dynamics point to two key aspects of innovation creation: first, high-impact innovations are typically developed with the participation of multiple parties, such as universities, businesses, and governments. Second, start-ups are more effective in developing innovations during times of crisis or economic downturn, which is what we are seeing now. With these aspects in mind and using the triple helix model, this study analyzes how the interaction of actors affects the quality of the startup ecosystem for international development. The value of the article for our research is that it reveals the importance of interaction between universities, enterprises and governments in the process of creating innovations, and also draws attention to the role of startups in times of economic crisis. The triple helix model allows for a deeper understanding of the impact of various actors on the development of the startup ecosystem from a global perspective.

Despite the existence of research in this area, the issue remains unresolved and requires further study. In particular, it is necessary to determine the optimal mechanisms of interaction between public authorities and innovation institutions to ensure effective management of innovation processes. An important aspect is also the coordination of strategic development priorities, which will help to increase the competitiveness of the national economy. In addition, the regulatory framework governing the activities of participants in the national innovation system should be improved to create favorable conditions for innovation.

Methodology

As part of the scientific study of the interaction between public authorities and innovation institutions as an influence on the development of the national innovation system, the article uses various research methods. These include:

– systematic approach - consideration of the essence of the national innovation system as a complex of interrelated elements, including government agencies, private enterprises, educational institutions, research organizations and international cooperation;
– comparative and historical method - comparison of the points of view of Ukrainian and foreign scholars of different periods of research on the formation, functioning and development of the national innovation system;
– modeling - visualization of the factor model of systemic interaction between public authorities and innovation institutions both in the process of development of the national innovation system and during its functioning;
– abstraction - identification of key characteristics of the relationship between public authorities and innovation institutions in the context of the development and functioning of the national innovation system;
– statistical analysis - consideration of trends in the development of technology parks in Ukraine, their impact on the innovation activities of industrial enterprises, changes in the number of innovative products introduced;
– analysis and synthesis - identification of key challenges in the functioning and development of the national innovation system, in particular, weak interaction between public authorities and innovation institutions, as well as the impact of legislative changes on the activities of technology parks in Ukraine;
– generalization - formulation of recommendations for improving the mechanisms of state support for innovation, development of public-private partnerships, and attraction of international investments.

Results

Article 9 of the Law of Ukraine "On innovation activity" (On innovation activity, 2002) stipulates that the central executive body responsible for the formation of state policy in the field of innovation provides regulatory and legal regulation, promotes the development of innovation activity in Ukraine and supports the national innovation system. Currently, domestic legislation does not contain a clear definition of the term "national innovation system." The scientific community also lacks a unified approach to understanding this concept. The innovation system is the institutional basis for innovative economic development, and its activities create conditions for the transformation of ideas and new knowledge into practical innovations, contributing to economic or other positive effects (Ivanova, 2024).

Ukrainian researcher Vysotsky points out that the concept of "national innovation system" has recently been increasingly used in various sources, including scientific papers, official documents, and current legislation. Of particular interest is the definition of this term proposed by the Organization for Economic Cooperation and Development (OECD). According to the OECD approach, the national innovation system is a set of public and private sector institutions that, both individually and in cooperation, contribute to the development and dissemination of the latest technologies within a particular country (Vysotsky, 2023).

Exploring the concept of "national innovation system", (Vysotsky, 2023) identifies its main features. The national innovation system is a complex of economically, organizationally and legally interacting entities that include participants in scientific, scientific, technical and innovation activities, innovation infrastructure, as well as authorized state and local government bodies responsible for innovation activities. The actors of the national innovation systems are focused on active participation in the promotion, provision or development of innovations, and their activities are aimed at conducting research and development with subsequent application in various sectors of the economy, including the real sector, as well as in the social sphere. The analysis of the above approaches influences the formation of the following definition: the national innovation system is an organized set of interconnected subjects of scientific, scientific, technical and innovation activities, innovation infrastructure, as well as public authorities and local governments engaged in the development, provision and support of innovation activities (Vysotsky, 2023).

Innovation activities in developed countries are shaped by the triple helix model. Its concept is based on the interaction of the three main actors of innovative development - the state, business and science. They are the basis for implementing changes, strengthening them and ensuring sustainable economic development. The interaction of these three sectors helps to create conditions for the effective use of scientific achievements in production, stimulates entrepreneurial activity and a favorable regulatory environment. The state provides support and regulation

of innovation processes, business financing and commercialization of the latest developments, while science generates new knowledge and technologies. This synergy contributes to the country's competitiveness and improves the welfare of society (Kijek & Matras-Bolibok, 2019).

Ukrainian scientist (Bazhal, 2017) notes that a new type of universities is being created and actively operating in the world today, operating in the mode of the "triple helix" management model, which involves the formation of a number of mechanisms and norms of cooperative interaction of all stakeholders in the innovation cycle - universities, industry, government and research institutions, which are established and actively operate for the cooperative generation and commercialization of innovations. Within the framework of such interaction, leading universities have powerful capabilities to effectively complete the innovation cycle of scientific and technical developments, which consists in bringing innovative products to the market. In Ukraine, according to the researcher, the management model of the "triple helix" is not functioning and is not programmed due to the lack of special legislative norms and appropriate legal support (Bazhal, 2017).

It is worth noting that the reasons that affect the functioning of the triple helix model should be sought in the subjects of scientific activity, as they are the source of new knowledge, technologies and innovative ideas. Their activity and interaction with business and the state determine the effectiveness of the processes of commercialization of scientific developments and introduction of innovations into production. In addition, the level of funding for the scientific sphere, access to modern infrastructure and the quality of training directly affect the dynamics of the innovation ecosystem. Therefore, in agreement with Bazhal, we note that the successful functioning of the triple helix model largely depends on the support of science and its integration into the country's economic processes.

Jovanović, Savic, Cai, Levi-Jaksic (2022) in their own study analyzed the country's development performance indicators based on the triple helix. Figure 1 shows the performance indicators based on the triple helix of OECD countries.

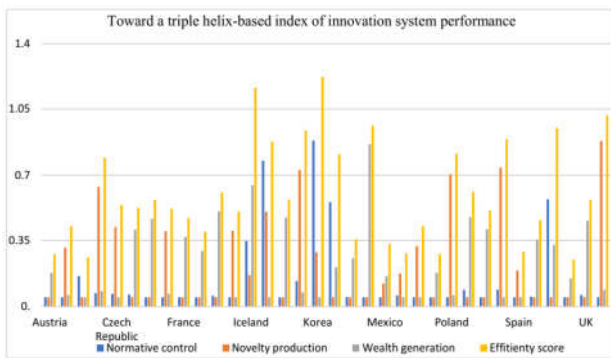

Figure 1. Toward a triple helix-based index of innovation system performance
Source: (Jovanović et al., 2022)

The analysis shows that ten countries demonstrate high efficiency in regulatory control, with an efficiency score above 1. In the first stage, the best performers were South Korea, Iceland, and Latvia. South Korea's high score is due to its high level of patent activity (0.9554). Latvia is characterized by high publishing activity (0.7803), as well as significant indicators of trade exports (0.1123) and patenting (0.1024). Iceland is highly ranked due to its intellectual property revenues (0.9850), which far exceed its invested resources. On the other hand, Mexico, Germany, and Turkey have low effective scores (0.278, 0.362, and 0.368, respectively). Turkey, despite significant public investment in the General Electric and Regenerative Chemical Industries, has low commercialization of intellectual property (0) and limited exports (0.005). Mexico has high imports (0.6450) and exports (0.3490), but its score is lowered due to the low number of patents and IP certificates. Germany, despite its strength in patenting (0.6782) and trade exports (0.2947), does not compensate for the lack of commercialization of intellectual property and the small number of published works (Figure 2).

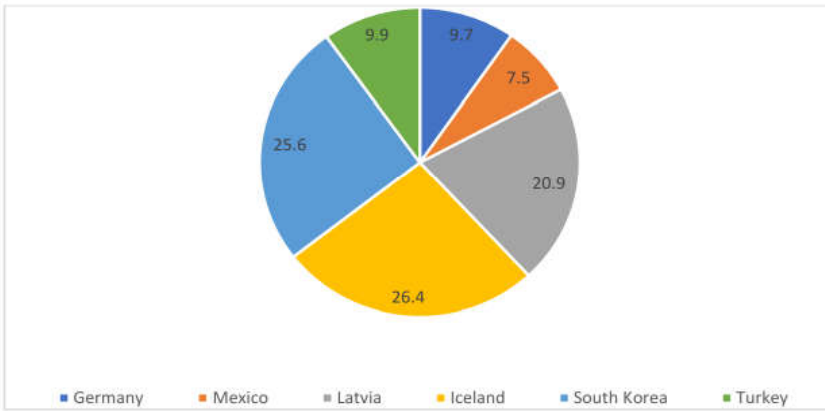

Figure 2. Performance indicators of regulatory control after the implementation of the triple helix model in countries

Source: (Jovanović, 2022).

In their research, (Dyachenko & Nazarenko, 2004) note that the triple helix model is a development of the prototype of the theoretical and philosophical understanding of forms of self-organization and cooperation within the framework of evolutionary theory. The main conceptual approach of this theory is based on the inertia of technological development trajectories, which have a decisive impact on economic growth. The trajectory of technological development formed in a certain historical period is an indicator of the type of economic and political system. According to this theory, countries that focus on the production of final consumption goods usually have a democratic and decentralized governance structure.

The main provisions of this concept can be summarized as follows:
- Institutional and cognitive structures can lose their stability and adaptability to modern challenges under certain conditions;
- the process of coevolution of these structures contributes to the formation of new organizational models that temporarily solve the problems of inconsistency, complexity and uncertainty in previous systems;
- the time factor plays a leading role in these dynamic processes, but with its passage, new uncertainties and difficulties arise, which, in turn, provoke further cycles of coevolution.

The triple helix model is based on the principle of combining three sets of relationships. In the scientific literature, the most common variations of the model are the following triplexes: "science - technology - society", 'science - industry - nature', 'science - economy - government', 'science - business - state' (Dyachenko *et al.,* 2024).

The processes called the fourth industrial revolution (Industry 4.0) (Schwab, 2016) are radically changing modern requirements, contributing to the efficiency and quality of the higher education system. Leading international analytical organizations have already conducted in-depth research on future changes in the labor market and the required level of labor force qualifications. In particular, the UNESCO Science Report "Toward 2030" (UNESCO, 2015) emphasizes the crucial role of science in economic development and the importance of universities as key players in this process. The document states that universities play the role of not only educational institutions, but also powerful drivers of innovation, as they are able to consider endogenous factors of economic growth that significantly affect the development of national innovation systems (Kniazevych *et al.,* 2018).

In the Ukrainian context, the triple helix model operates on the basis of increased flexibility and the ability to effectively manage difficult situations. This process includes the development of contingency plans for R&D and technology projects, the introduction of flexible financial mechanisms that allow for the rapid reallocation of resources in accordance with priority needs, and the formation of an innovation culture focused on rapid response and adaptation to unforeseen challenges.

The triple helix model is a powerful mechanism for innovation development based on close cooperation between three main actors: universities, businesses, and governments. It promotes the creation of innovative products and technologies through the interaction of scientific research, business, and public policy. It is important to consider the practical implementation of this model both in Ukraine and in foreign countries to understand its mechanisms, effectiveness, and shortcomings.

In developed countries, the triple helix model is the basis for the development of innovation ecosystems. For example, the European Union currently has an

active program, in particular Horizon 2020, which promotes interaction between universities, research institutions, businesses, and government agencies. This program is a joint project developed with the participation of scientific institutions and businesses, and governments support this program through grants and other financial mechanisms (Qoqiauri, & Gechbaia, 2017).

In the United States, innovation hubs and parks are also widely used, where research and technology startups are supported at the state level. For example, the Stanford Research Park, which operates on the basis of Stanford University, has become an important center for the development of high technologies due to the close cooperation of the university, business, and local governments. In Germany, the Industry 4.0 program is also a prime example of the successful implementation of the triple helix model. Thanks to the integration of science and business, the country was able to become a leader in the development of the latest technologies for industry (Vertova, 2014).

In Ukraine, the triple helix model has not yet been implemented at the national level, although some projects in this direction exist. One such example is the activity of technology parks and innovation hubs, such as the Kyiv Innovation Center or the UNIT.City innovation park. The Institute of Technologies and Projects, which is part of Ukrainian science, operates in close partnership with private enterprises. However, there are barriers to interaction between them due to the lack of clear policy and legal support.

It should also be noted that within the "triple helix" model, which combines science, education, and innovative entrepreneurship, the role of the teacher is of particular importance. In the context of modern social relations, in particular the unstable nature of the scientific and pedagogical staff caused by martial law in Ukraine, it is crucial to preserve and develop the scientific and pedagogical staff. Instead of focusing entirely on a student-centered approach, it should be recognized that teachers play a key role in the transfer of knowledge, development of professional skills and competencies necessary for working in the innovation sector.

Teachers, as active participants in the scientific environment, play the role of a chain between theoretical knowledge and practical needs of the industry, making a significant contribution to the development of high-tech education. Their ability to introduce the latest scientific ideas, engage students in research activities, and adapt educational programs to current challenges is key to training professionals capable of promoting innovation in manufacturing and science (Lopatina *et al.,* 2024).

Moacir de Mirando Oliveira, President of the Triple Helix Association 2024-2026, noted that in a world focused on unity and progress, the Triple Helix methodology opens a transformative path for accelerated economic, social and environmental development, giving hope for a better future (Triple Helix, 2024).

The Triple Helix model can be used as a universal tool for solving problems at different levels - micro, meso, and macro. Its reliability is confirmed by the observation of the joint development of Stanford University and Silicon Valley. For example, Dyachenko and Nazarenko emphasize that the Triple Helix concept leads to the continuous creation of innovations. This model is characterized by a high density of high-tech companies (computers, components, including microprocessors, software, mobile communications, biotechnology, etc.) and a concentration of leading universities. The model is based on the theory of the dominant positions of institutional structures that facilitate the creation of new knowledge, as well as the importance of the network nature of interaction between participants in the innovation process within strategic associations where the three subjects of relations intersect. The model is a horizontal approach to innovation policy, which is perceived not so much as an initiative coming from the government, but as the result of interaction at different levels, including the regional level, between government agencies, businesses, universities, academia, and non-governmental organizations (Dyachenko *et al.,* 2024).

The Triple Helix model focuses on the interaction of the three main elements - government, business and universities - ensuring innovative development through their cooperation. However, over time, there is a growing understanding that to achieve sustainable and inclusive development, it is necessary to involve more actors reflecting a wide range of impacts on society. The proposed Penta Helix model expands on this concept by including two more important elements in the process: civil society and the media. Civil society represents the interests of the population, actively influencing decision-making, which is important for ensuring social responsibility and sustainable development. The media, in turn, are becoming important channels for disseminating knowledge and information and contributing to the formation of public opinion on innovative initiatives. Thus, Penta Helix approaches the innovation ecosystem as a complex process where each participant - from governments to citizens - contributes to solving global problems, ensuring sustainable development and creating new opportunities. It is worth emphasizing that the need for additional chains has been questioned (Zhou *et al.,* 2021). The inclusion of civil society as a separate entity contributes to more effective implementation of innovations through social responsibility and participation of local communities in decision-making processes. At the same time, media engagement ensures information transparency, popularization of innovative technologies, and strengthening of social capital. Thus, the Penta Helix model creates conditions for sustainable development, as it takes into account diverse interests and promotes balanced economic growth, taking into account environmental and social aspects (Krysovatyy & Ptashchenko, 2023).

Given the latest trends in sustainable development, the Penta Helix concept is closely linked to the principles of Environmental, Social, and Governance (ESG), which define the criteria for responsible management and sustainable business. Integration of environmental (E), social (S), and governance (G) aspects

into decision-making processes helps to reduce negative environmental impact, strengthen social responsibility, and ensure long-term sustainability of innovative organizations. Within the Penta Helix model, the environmental component is of particular importance, as business, government, science, civil society, and the media can jointly formulate strategies for a "green" transition and energy efficiency. Thus, the combination of Penta Helix and ESG approaches contributes to the creation of an effective platform for innovative development that not only ensures economic growth but also promotes social cohesion, responsible resource management, and long-term environmental safety.

Duma & Kachmar (2024) emphasize that Russia's full-scale invasion of Ukraine has affected the development of the country's startup ecosystem. Despite the difficult wartime conditions, many Ukrainian startups were able to adapt to the new realities and continue their operations. In times of war, the top priority remains meeting the basic needs of the population, driven by innovative projects to ensure security, stable access to the Internet and electricity. These solutions improve the quality of life of citizens and ensure the country's further development.

The investment climate in Ukraine is currently going through a difficult time. Until 2022, Ukraine was not the most attractive destination for international investors, and the war has made the process of raising funds even more difficult. Currently, investments in domestic startups are accompanied by high risks. At the current stage, there is an active migration of Ukrainian startups abroad. About 30% of them have moved to other countries, forming new cooperation networks and establishing links between the Ukrainian startup ecosystem and international communities.

Given the restrictions imposed by the military conflict on economic development and the investment climate, government support, attracting international financing, and integration into global innovation networks are key to the sustainability of startups. An important step now is to develop a long-term strategy for the development of the startup ecosystem for 2025-2030, which will include comprehensive changes to create favorable conditions for the commercialization of innovations and cooperation with international partners. The strategy should include the identification of priority areas that will help strengthen the country's innovative development, allowing Ukrainian startups to increase their competitiveness when entering the global market (Duma *et. al,* 2024).

Grabovenko and Kolosov (2024) point out that in order to produce innovations by transforming scientific ideas and supporting innovation cooperation, technoparks have been created and have become widely popular in the world. Technoparks have different names: research parks, science and technology parks, innovative business parks, techno-cities, technopolises, and innovation and technology centers (ESCAP, 2019).

The term "technology park" first appeared in 1951, when a technology park was established in the US, in the city of Palo Alto (California), at Stanford

University, which became the first innovative facility of this type. The development of technology parks in Europe lasted for about twenty years. In the late 1960s, the universities of Cranfield and Cambridge in the United Kingdom launched activities in this area. Although their influence was initially insignificant, in the 1980s the British government encouraged universities to engage more actively with industry, which led to the emergence of a second wave of technology parks. By the 1990s, more than half of British universities were already cooperating with science parks. In the 1970s, the Sophia-Antipolis technology park was created in France, and in the early 1980s, science parks appeared in Italy and Germany, including AREA in Trieste and the technology park in Heidelberg (Gabovenko *et al.,* 2024).

As of 2015, there were more than 400 science parks in the world, while according to a 2013 report by the European Union, 366 science and technology parks were recorded in EU member states (UNIDO, 2021).

As important elements of innovation ecosystems, technology parks play a key role in implementing the principles of the Penta Helix and ESG model. Thanks to their ability to bring together business, science, government, civil society, and media, technology parks are becoming platforms for the creation and implementation of green technologies, energy-efficient solutions, and sustainable business practices. They contribute to the development of new technologies that reduce the negative impact on the environment while creating jobs and economic growth. In the process of developing technology parks, scientists are actively working on the development of innovative products and services that meet high standards of environmental and social responsibility, which, in turn, contribute to sustainable development at the level of local and international communities.

At the same time, technology parks have the opportunity to integrate management tools and skills in accordance with ESG principles, allowing organizations within the technology park to formulate strategies aimed at preserving the environment, supporting social inclusion and increasing corporate transparency. Interaction between various ecosystem participants - enterprises, research institutes, government agencies, and public organizations - allows us to develop new solutions for sustainable development that take into account the interests of all stakeholders. This, in turn, ensures not only increased innovation capacity, but also stability in markets, adaptation to climate change, and support for social responsibility in the face of global challenges.

Technology parks are important institutions for stimulating innovation and developing high-tech industries around the world. Let’s take a look at a few examples of such technology parks. For example, Campinas Technology Park is one of the largest innovation centers in Brazil. It was created to stimulate the development of high-tech industries such as biotechnology, information technology and pharmaceuticals. Campinas works closely with the University of Campinas, making an effective combination of science and business. This technology park

facilitates access to the latest scientific developments that are actively used by successful high-tech companies.

Dubai Silicon Oasis (DSO) is one of the most developed technology parks in the Middle East. It actively supports innovations in such industries as information technology, electronics, nanotechnology, and renewable energy. DSO provides favorable conditions for startups, including preferential tax rates and infrastructure support, which facilitates the development of high-tech companies. This technology park has become an important center of innovation in the UAE and an international hub for entrepreneurs and investors (Dubai Silicon Oasis, 2025).

King Abdulaziz City for Science and Technology (KACST) is one of the leading research centers in Saudi Arabia that promotes innovation and high technology in the country. KACST is active in such areas as aerospace technology, biotechnology, energy, and information technology. The center cooperates with international companies and scientific institutions, supporting startups and the development of new technologies. Thanks to the active support of the Saudi government, KACST has become an important institution for the development of science and technology in the country.

The Saudi Arabia Center for Science and Technology (SANCST) was established in 1977 as an autonomous governmental organization responsible for the development of science and technology, as well as the coordination of scientific efforts of various institutions in the country. The main goal was to promote applied research to create a technical base that supports the development of agriculture, industry, medicine and the environment, benefiting various sectors of the economy. The main task of KACST is to create an infrastructure to support scientific research in Saudi Arabia, which includes managing research grants, establishing communication networks and databases, and conducting applied research at institutions such as: Energy Research Institute, Space Research Institute, Computer Science and Electronics Research Institute, Atomic Energy Research Institute, Petroleum and Petrochemical Research Institute, Natural Resources and Environment Research Institute, and Astronomy and Geophysics Research Institute (Kingdom of Saudi Arabia, 2025).

Zhongguancun Technology Park is located in the capital of China - Beijing. It is often called the “Chinese Silicon Valley”. The technology park was founded in 1988 and has become one of the largest innovation hubs in the country. Zhongguancun focuses on information technology, biotechnology, environmental technology, and emerging technologies. The technology park actively supports start-ups by providing them with funding, advice and access to research, in close cooperation with large international corporations. It is home to the offices of major technology companies such as Baidu, Lenovo, and DJI.

Zhongguancun Software Park (Zpark) is a specialized technology park focusing on research and development in the software and IT outsourcing industry. Established in 2001, the park began expansion in 2011 with the construction

of a second phase with an area of 3 million m^2 with the concept of a "floating island in a forest sea". Sustainability plays an important role in the design, with 60% greening in the first phase and a building height limit of 13 meters. Zpark is home to 726 companies, including international giants such as Oracle, IBM, Thomson Reuters, as well as leading Chinese enterprises including Lenovo, Baidu, Tencent and others. The park also has more than 78,000 employees and is an important center for innovation in various industries such as energy, transportation, communications, finance, and defense (ZGC Software Park, 2025).

Technopark Trivandrum, Kerala is one of the largest technology parks in India. It was founded in 1990 in the city of Trivandrum, Kerala. The main goal of Technopark is to develop the software and information technology industry. Technopark supports startups and companies working in the field of software, IT consulting, biotechnology, and engineering. Technopark provides favorable conditions for the development of such companies, including preferential tax rates and infrastructure support. Among the well-known companies operating here are Infosys, TCS, and UST Global. Technopark is an important center for the IT industry in India and creates jobs for thousands of people in the technology sector (Harmony of work, 2025).

Ukraine does not stand aside from innovations, despite the fact that it has faced many challenges. After 2022, the situation did not change, but grew larger. As of 2023, according to Y. O. Ogrenovych and V. S. Karmazina, the number of registered industrial parks included in the Register is 61. In 2022, 16 such parks were submitted for registration, but as a result, only 9 were registered in different regions of the country. Among them are the following: "Western Ukrainian Industrial Hub, Maramures, L-Town, Malin-Zakhid, Energy of Bukovyna, Khotyn-Invest, Volodymyr, Eco-Smart Industrial Park GALIT, and Uzhhorod. Other innovative parks in Ukraine include the Economopoli-HTZ of entrepreneur O. Yaroslavsky, as well as UNIT.City, LvivTech.City, and UNIT.City Kharkiv of V. Khmelnytsky. Among the residents of these parks are the Swiss company Syngenta, as well as Ukrainian projects such as SolarGaps, Delfast, and Cardiomo.

Among the main incentives for the development of technology parks are preferential conditions from the state, including tax cuts, as well as a number of advantages for businesses in Ukraine that help attract companies to technology and industrial parks. This includes, in particular:

– Economic benefits in the process of building an industrial enterprise on the territory of the park, contributing to savings of about 25% of investments;
– Logistics benefits, which provide savings of 7-10%, as logistics costs during the war are partially covered by manufacturers and traders of the technology park;
– Support for business development and identification of new ways of cooperation with enterprises that would be difficult to interact with under normal conditions;

– Special programs and financial benefits for innovative enterprises operating in technology and industrial parks. This may include access to additional sources of funding, support for research and development, and technological advice;
– Support for export activities of technology park residents by attracting international partners, organizing exhibitions, presentations, and facilitating foreign economic activity;
– Development of the park's educational and scientific resource by promoting cooperation between parks, educational institutions, research centers, and research institutes (Ogrenevich *et al.,* 2023).

For effective public administration of the development of the national innovation system, it is important to choose a policy area in which innovation-related processes are most integrated, in particular in the areas of education, science, technology, investment and intellectual property. The key system-forming areas are: higher education, which promotes the development of entrepreneurial skills and the creation of innovative goods and services; public-private partnerships, which combine the resources and skills of the private sector with the regulatory functions of the state; research and innovation, which covers basic and applied research and the commercialization of results; and government regulation, which supports innovation through the regulatory framework, financial support and incentives. Each of these areas interacts with and complements the other, contributing to the creation of competitive products and services in the international market. Thus, effective governance in these areas ensures rapid economic growth and improved quality of life for citizens (Khimenko, 2020).

Green energy remains a priority for the development of innovative technologies. As a group of domestic researchers rightly notes, green energy is a set of energy production technologies that minimize environmental pollution, including greenhouse gas emissions. It is based on the use of renewable and inexhaustible sources, such as wind energy, solar radiation, and hydropower. The most popular types of green energy are hydropower, wind power, solar power, bioenergy, and geothermal energy (Mykhaylova *et al.,* 2023).

As of 2025, renewable energy sources play a key role in ensuring Ukraine's energy independence. Before the full-scale invasion, the green energy sector was actively developing, attracting both domestic and international investors, and gradually increasing its capacity. However, the war has dealt a significant blow to the sector, causing the destruction and shutdown of many facilities, a financial crisis, and the suspension of construction of new wind farms. Currently, the main task in the scientific and economic space remains the search for alternative energy sources, the development of a circular economy, and the organic interaction of elements and resources in this area with government institutions. It is the state's support that can organize and strengthen the impact on the innovation of economic development for the benefit of society and the full development of the state. A group of researchers

(Sytnyk, Zubczyk, Orel, 2022) point out that innovative development involves the transformation of state institutions, the introduction of new organizational and legal mechanisms, as well as the modernization of political and administrative processes that would affect national security in the context of its formation. At the same time, globalization will contribute to the formation of a "transnational bloc" of businesses, government officials and intellectuals focused primarily on making profits rather than protecting national interests, while political technologies can be used to manipulate public opinion on the way to identifying innovative priorities. Among a number of key tasks of the authorities, it is necessary to highlight the support of permanent and irreversible transformations of state institutions aimed at qualitative renewal of their activities (Sytnyk *et al.,* 2022). We believe that such transformational processes can include digitalization and automation of government processes, reform of governance structures, ensuring transparency and accountability, improving institutional capacity, timely response to economic and social changes, formation of inclusive governance and development of innovation policy and stimulation of startups. These transformational processes will affect the focus and quality of public services, the formation of an effective institutional structure that will respond to changes, and the strengthening of public trust in the state through transparency and accountability.

The success of the postwar reconstruction and development of the Balkan countries is also associated with the implementation of the triple helix model. Researchers S. L. Schultz and O. M. Lutskiv note that armed conflicts lead to significant economic and social consequences. The main problems are rising unemployment and decreasing purchasing power, expansion of the shadow economy, weakening of state institutions, and concentration of resources on military needs. There are also difficulties with food security due to the destruction of logistics and the loss of agricultural land. The environmental situation is also deteriorating, and states are facing financial difficulties. In this context, the postwar reconstruction program of the Western Balkan countries, which managed to achieve a high level of development through structural transformations, is effective. Military operations in the Balkan countries led to large-scale destruction and human losses: 2.3% of the population was killed, more than 2 million people were internally displaced, and 2,000 people went missing. The consequences also included high unemployment, the expansion of the shadow economy, and low levels of domestic investment and savings (1% to 3% of GDP). The economic potential suffered significantly: industrial production dropped to 25% of pre-war levels, and unemployment reached 40%. To overcome the consequences of the war, institutional reforms were implemented to bring the Balkan countries closer to the EU and attract international financial assistance, among other things:

– The Stabilization and Association Process (SAP) was introduced by the European Commission in May 1999. Its main goal was to ensure peace and stability, promote economic development in the region, and create conditions for the countries' integration into the EU;

– The Agency for the Coordination of International Assistance, which focused on interacting with donors and ensuring effective planning and implementation of post-war reconstruction programs (Post-war reconstruction of economy, 2023).

Bosnia and Herzegovina was the most affected country in the Balkan region during the war. The post-war reconstruction of the Balkan countries was financed by international assistance from the United States, Germany, Great Britain, France, as well as the World Bank, IMF, EBRD, USAID and other organizations. From 1996 to 2005, Bosnia and Herzegovina received 9 billion US dollars, and international aid exceeded 20% of the country's GDP.

The main financial instruments were:

– Grants are the dominant form of aid (82% of the total, $5.95 billion by 2005);
– EU programs - PHARE (support for EU integration), SAPARD (agricultural development), OBNOVA (infrastructure reconstruction and support for civil society);
– Targeted financing - EBRD and World Bank funds were used to restore transport, energy, agriculture, healthcare, social protection and the environment;
– Non-profit organizations - actively supported local authorities in rebuilding infrastructure and developing civil society (Flechas *et al.,* 2023).

Croatia's post-war reconstruction was successful due to the smaller scale of destruction (only 20% of the territory was damaged) and the rapid involvement of the rear regions in economic activity (Švarc et.ol, 2014). CSERP's own strategy, which included investment in communities, social cohesion, and transparent use of international aid, played an important role. Funding was provided by programs of the EU, the World Bank, the EBRD, budget taxes, and non-governmental organizations. Reconstruction priorities included road construction, tourism development, and shipbuilding, which generated exports worth $7 billion in 2000. Thanks to effective reconstruction, Croatia restored its pre-war GDP level in 2003, and in 2013 it became a member of the EU. In general, global experience shows that postwar GDP per capita growth did not exceed 2% per year. At the same time, in all the countries analyzed, economic growth rates after the conflict were higher than before it began (Schultz *et al.,* 2023).

Speaking about the effectiveness of interaction between public authorities and innovation institutions in Ukraine, it is advisable to analyze the peculiarities of the development of technology parks in Ukraine as recipients of state support and, at the same time, as an influence on the innovation activities of industrial enterprises (Table 1).

Table 1. Innovative activities of technology parks and industrial enterprises in Ukraine from 2000 to 2023.

Year	Number of innovative products introduced	Number of accepted technology park projects
2000	15323	60
2001	19484	29
2002	22847	11
2003	7416	8
2004	3978	0
2005	3152	0
2006	2408	2
2007	2526	6
2008	2446	4
2009	2685	0
2010	2408	0
2011	3238	0
2012	3403	0
2013	3138	0
2014	3661	0
2015	3136	0
2016	4139	0
2017	2387	0
2018	3843	0
2019	2148	0
2020	4066	0
2021	1756	0
2022	2347	0
2023	2715	0

Source: developed by the author based on Voloshyna et al. (2017).

The largest number of accepted innovation projects of technology parks in the period 2000-2001 helped to accelerate the process of introducing new types of products by industrial enterprises - from 15323 to 22847 items. In the following years and until the end of 2005, the opposite trend was observed - the number of accepted technology park projects gradually decreased. In 2005, this figure

reached zero. However, since 2006, the situation has remained unchanged. Thus, from 2003 to 2006, the number of new types of products decreased to 2408 items.

In 2007, 2 technology park projects were implemented in Ukraine, and the total number of new innovative products increased to 2685. By the end of 2008, despite an increase in the number of accepted technology park projects to 6 sites, the number of new innovative products decreased to 2446. In 2009, with the introduction of 2685 new products, 4 technology park projects were submitted for consideration.

This situation indicates the beginning of a systemic crisis in the national innovation system, when lack of funding limited the ability of industrial enterprises to develop innovative production, and the termination of support for innovative projects of technology parks by government agencies effectively stopped their activities from 2010 to the end of the analyzed period.

Following the adoption of the Law of Ukraine "On Amendments to the Law of Ukraine 'On the Special Regime of Innovative Activities of Technoparks' and Other Laws of Ukraine" (Law of Ukraine, No. 3333-IV, 2006) and the Tax Code of Ukraine (Tax Code of Ukraine, 2010), when almost all benefits for each category of taxpayers operating in the territory of technoparks were canceled, the actual activities of technoparks were virtually suspended, which significantly affected the innovation activity of industrial enterprises. As a result, industrial enterprises in Ukraine were forced to operate in the mode of maximum resource saving and limited introduction of new types of innovative products (Das *et. al.,* 2024).

In the period from 2010 to 2023, the process of introducing new types of products experienced moderate fluctuations at a relatively low level. By the end of 2019, the number of such products decreased to 2148 units, reaching the lowest value for the entire analyzed period. However, with the outbreak of the COVID-19 pandemic, this figure increased to 4066 units, which could have been an impetus for the introduction of new types of technological products, in particular for the integration of information and communication technologies (ICT) into the activities of many business institutions that have switched to online operation.

By the end of 2021, the outbreak of the pandemic led to the shutdown of many industrial enterprises, causing a decrease in the number of innovative products introduced to 1756 units. Subsequently, due to the full-scale war, some industrial enterprises, in particular from the defense industry, stepped up their activities in response to a significant increase in military needs, contributing to a gradual increase in the number of innovative products introduced, reaching 2715 units by the end of 2023.

The results of the study indicate that the activities of Ukraine's technology parks do not correspond to the concept of the national innovation system. The functioning of technology parks in Ukraine was largely based on the capabilities of industrial enterprises and the capabilities of scientific institutions without proper support from government agencies. Importantly, throughout the entire period of

their operation, no state or local targeted programs were developed to implement innovative projects.

In addition, investors faced uncertainty, which forced them to constantly adjust the technical and economic parameters of investment proposals, leading to delays at all stages of decision-making on the implementation of new technology park projects. As a result, the lack of funding for innovation activities gradually led to the closure of technology parks. The results of the analysis show that this situation significantly slows down the development of the national innovation system, in particular in terms of stimulating the innovation activities of industrial enterprises (Bogatyreva *et. al.,* 2022).

On the other hand, information from the official website of the newly created Ukrainian innovation park UNIT.City in Kyiv indicates that Ukraine has high technological capabilities to move from a raw material economy to an economy of innovative development and national income. However, for the national innovation system to function effectively, it is necessary to create appropriate conditions that would form the basis for resolving conflicts and protecting interests among economic actors. In particular, there are still a number of unresolved issues regarding the mechanisms for approving and implementing innovative projects involving public authorities, industrial enterprises, and research institutions. This, in turn, greatly complicates all stages of the investment process and hinders the development of innovation.

Technoparks in Ukraine, despite a number of opportunities, have not been able to become an effective tool of the national innovation system. This indicates insufficient support from government agencies and a lack of favorable conditions for the development of innovative institutions. Some of them still have suspended or incomplete registration processes, which limits their ability to contribute to economic growth and technological change. The main obstacles are not only the lack of funding, but also the weak interaction between the authorities and innovation institutions, which slows down scientific and technological development and reduces the quality of education and training of highly qualified personnel.

The innovative development of a country is determined by the ability of society to effectively use the available human capital resources, ensuring their integration at all levels of the national innovation system. People endowed with physical and intellectual resources are the generators of new ideas. Their interaction creates a competitive economy focused on the development and implementation of the latest technologies (Tkach, 2024).

The concept of the triple helix is based on the interaction of universities (science), business (industry), and the state (government) in the process of innovative development, and the role of human capital, described earlier, is directly related to the functioning of the triple helix and innovative institutions. Thus, human capital and universities are interrelated categories. Universities act as a center of knowledge, generating new ideas and research. They train qualified

personnel, who can then integrate into business or government structures. This is how knowledge is transferred and an innovative culture is formed. Business and commercialization of innovations is the second step of the triple helix. The private sector (business) uses scientific developments, turning them into technologies, products and services. By investing in start-ups and R&D, companies contribute to the formation of a competitive economy focused on innovative technologies. The state, as a regulator and investor, provides institutional support, including research funding, creation of technology parks, and development of legislation to protect intellectual property. It also helps to stimulate cooperation between universities and businesses, supports startups, and guides the economy on an innovative path of development.

In sum, the triple helix allows countries to effectively utilize their human capital, transforming knowledge into practical innovations. Without this connection, scientific ideas remain theoretical and business remains technologically backward. It is the state, universities, and business that together create the conditions for sustainable and long-term innovative development.

Discussion

It is expected that in 2025, technology parks will play a key role in rebuilding Ukraine after the war, contributing to the development of military technologies and utilizing the available human resources. The war has seen an active development of military technologies, including unmanned systems. Ukrainian companies, with the support of government programs, have significantly increased the production of drones and other automated equipment that are actively used by Ukrainian defenders at the front (Gunder, 2024).

In December 2024, the Strategy for Digital Development of Ukraine's Innovation Activity for the period up to 2030 was approved, which envisages the active introduction of digital technologies in various areas, including defense (On approval of the Strategy, 2024).

Currently, the overall picture remains complex, with ongoing hostilities in the east and south of the country. This process requires continuous improvement of military technologies and adaptation to new conditions (Review of the situation, 2025). Work in this direction is ongoing. Ukraine is slowly improving mechanisms for rapid adaptation and flexibility of military technological development processes. For example, the Delta platform is a seamless integration of public and private digital capabilities. The system was actively used to organize the defense of Kyiv, Kharkiv and Kherson counter-offensive operations and the sinking of the cruiser Moskva, and integrates intelligence with surveillance, target capture and reconnaissance missions. "Delta is just one of numerous complex projects initiated by non-governmental organizations and defense startups aimed at developing military defense. In particular, teams such as Army SOS and UA Dynamics have

raised funds to develop and produce the Kropyva guidance software, as well as Valkyria and Panisher reconnaissance and attack drones. Working closely with military units at the front, they developed tactics and procedures for the effective use of these drones, as well as improved fire adjustment procedures.

On the state side, the biggest initiative was taken by Ukraine's special services and intelligence, which turned to volunteers and private donors to bring in commercial technology for operations of strategic importance. This resulted in the development of the Beaver fixed-wing drone, capable of precisely targeting enemy missile production and storage facilities, as well as the Sea Baby surface drone, designed to attack the Kerch Bridge.

Ukraine's defense innovation ecosystem today consists of hundreds of Ukrainian and international organizations implementing thousands of projects. They are becoming increasingly capable of supplying the necessary technologies. However, the impact of the military-technical revolution depends on the ability of the defense establishment to correctly identify operational challenges and develop policies that ensure fast, efficient and realistic implementation of the capability development process. Today, such a capability and policy do not yet exist.

Ukraine has achieved significant results thanks to a bottom-up model of defense innovation that developed during the ten years of war. Ongoing efforts to accelerate the development of the Ukrainian defense industry and scale up platform production, such as the production of one million drones, are important, but they alone cannot match available technologies with specific mission needs.

Classical approaches to capability development are too slow for new and disruptive technologies, and the special operations model is not designed to scale. Therefore, these approaches must be complemented by accelerated capability development that benefits all security and defense forces.

Establishing a capacity development accelerator for defense procurement and security cooperation would require minimal resources, but if resources are aligned with priorities and the pace of innovation is accelerated, it could lead to important changes (Military-technical revolution in Ukraine, 2024).

As of 2025, technology parks in Ukraine are at the stage of active development, but still face a number of challenges. The main problems include the lack of adequate support from the state, insufficient funding, and poor integration between government agencies, research institutions, and businesses. Despite the challenges, technology parks, including UNIT.City, LvivTech.City, and other innovation platforms, have significant chances to develop and support startups and innovations. In particular, technology parks actively support such areas as defense technology, industry, ecology, and green energy.

Defense is one of the key sectors, so the development of technology parks in this area will help to develop the latest technologies for the army, including unmanned aerial vehicles, communication systems, automated control systems, and other defense facilities. Technology parks that cooperate with defense industry

enterprises are enhancing their development by promoting innovations in these industries. This process is extremely important in times of war.

Industry is also one of the priority areas for innovation, particularly in the context of automation of production processes, robotics, and the development of new materials and technical solutions for traditional industry. The areas of ecology and green energy are gaining more and more attention due to the need for transition to sustainable development, in particular through the development of renewable energy sources, electric vehicles, energy conservation technologies and water purification.

Thus, the prospects for the development of technology parks in such areas as defense, industry, ecology, and green energy can be important solutions for ensuring sustainable economic development and the technological future of Ukraine. However, to be fully effective, cooperation between the state, scientific institutions, and business needs to be significantly strengthened, and favorable conditions for investment need to be created.

Conclusion

The effectiveness of the national innovation system (NIS) directly depends on the level of interaction between public authorities and innovation institutions. The analysis of the development of technology parks in Ukraine shows that legislative changes aimed at abolishing tax benefits have actually led to the termination of their activities, which has negatively affected the innovation activity of industrial enterprises. The main obstacles to the development of the NIS remain the low level of commercialization of scientific research, weak coordination between government, business and scientific institutions, and limited access to financing for innovation projects.

Overcoming these challenges requires the resumption of technology parks by introducing incentives for investors, including tax breaks and simplified access to financing. At the same time, public-private partnerships (PPPs) will help attract additional resources for research and development, as well as stimulate cooperation between the public and private sectors. Since integration into the global innovation space is a key condition for increasing competitiveness, it is necessary to attract international experience, ensuring the participation of Ukrainian technology parks in global innovation programs and expanding access to advanced technologies.

Further research should be focused on developing mechanisms to stimulate investment in the innovation sector, in particular through the development of venture capital financing, crowdfunding platforms, and government co-financing programs. Another important area is the modernization of educational programs and strengthening the role of research in higher education institutions, which will help attract highly qualified specialists to priority sectors of the economy.

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