

APPROACH TO ACCELERATE THE CREATION AND IMPLEMENTATION OF THE ADVANCED SCIENCE DEVELOPMENTS BASED ON THE USE PROGRAMS OPEN INNOVATION AND INNOVATION ECOSYSTEMS

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Abstract: An analysis of the theoretical and methodological foundations of the development of the concept of open innovation and the innovation ecosystem approach had presented, which showed that in conditions of rapid changes in the dynamic macroeconomic environment, ecosystem economics emphasizes the need for cooperation between different organizations, companies and stakeholders to create shared value. In contrast to the traditional economy, where value is created through a linear value chain within the framework of innovation systems. The transition from the application of the innovation systems approach to the application of the innovation ecosystem approach is due to the transformational transition from the application of the concept of closed innovation within the framework of the linear innovation process to the application of the concept of open innovation within the framework of the open innovation process. It had established that new social and economic challenges encourage scientific institutions, government bodies, industry and civil society to close cooperation to accelerate the implementation of advanced scientific and technical developments that solve modern socio-economic problems. The interrelation and complementarity of the concept of open innovation and the approach of innovation ecosystems, which form a favorable environment for the creation and implementation of scientific and technical developments, had proven. The application of open innovation practices and innovation ecosystems had actively supported within the framework of European programs.

The results of the analysis of the activities of scientific institutions of the NAS of Ukraine had presented. A decrease in key indicators of innovative activity of scientific institutions of the NAS of Ukraine had established which due the fact that a significant part of scientific and technical developments remains non-commercialized. Scientific institutions of the NAS of Ukraine had differentiated into three groups according to the level of effectiveness of creating advanced scientific and technical developments. Key success factors of scientific institutions of the NAS of Ukraine with high innovative activity had identified and established.

Based on the analysis of the theoretical and methodological foundations of the development of the concept of open innovation approach of innovation ecosystems the conceptual approach to the formation programs of open innovation and programs of innovation ecosystems, synchronized with the principles and architecture of European programs had proposed. The application of the proposed approach allows overcoming the limitations of traditional approaches to the organization of research programs and ensures the application of the approach to accelerate the creation and implementation of the advanced science developments within the framework of open innovation programs and open innovation ecosystem programs.

Keywords: Ecosystem economics, ecosystem approach, open innovation, innovation ecosystems, European programs, scientific and technical developments, open innovation programs, innovation ecosystem programs.

1. Introduction

Modern companies and organizations are facing greater environmental uncertainty and are identifying the need to think outside the box to become more resilient [1]. They are not confine to traditional industries, but operate in complex, dynamic ecosystems spanning multiple sectors and disciplines. Their experience has shown that effective ecosystems are crucial for achieving sustainable growth and sustaining competitive advantage. In contrast to traditional industry economies, which focus on competition within narrowly defined boundaries of specific industries,

ecosystems emphasize collaboration and synergy between diverse, interconnected organizations, companies, and stakeholders [2, 3]. Unlike traditional economics, which focuses on individual organizations, ecosystem economics emphasizes the power of collaboration to create new value. In traditional economics, value had created through a linear value chain consisting of independent organizations focused on optimizing their internal processes. In contrast, ecosystem economics focuses on networked value creation, where value had created collaboratively through collaboration between different participants. An ecosystem allows for the integration of different capabilities and resources, leading to the creation of new value, innovative products, and services [4].

The ecosystem approach helps companies and organizations create interconnected services to meet customer needs. Many of the world's most successful companies and organizations use the opportunities of an ecosystem approach to grow and prosper [5]. The ecosystem approach allows for the consolidation of diverse actors, which may be located within or across traditional industry boundaries. This creates new opportunities for improving the efficiency of value chains, while simultaneously opening up new ways of creating value for a wide range of actors [6]. The ecosystem approach changes the way companies and organizations work and manage, including the formation of new roles and responsibilities that arise and are consistent with the grand challenges and megatrends shaping management practices of the 21st century [7].

In today's rapidly evolving world, no sector of the economy had left untouched by the application of the ecosystem approach and the emergence of ecosystems [8]. Ecosystems can provide significant advantages over traditional approaches to stimulate the growth of companies and organizations, as well as accelerate the introduction of new products to the market [9]. Ecosystem interactions help companies and organizations to provide a higher degree of flexibility, allowing them to quickly adjust their activities in accordance with changing circumstances [10].

Based on the analysis of the landscape of 40 ecosystems, it had found that different types of ecosystems have conceptual similarities in terms of forming communities or networks of companies/organizations that provide systemic solutions and services in certain areas of sustainable socio-economic and environmental development [11].

Innovation ecosystems occupy a special place in the ecosystem economy landscape. Innovation ecosystems act as catalysts for growth, creating environments where ideas can develop and accelerate innovation, where different ecosystems can support individual stages of the process of creating and implementing innovative scientific and technological developments [12]. Innovation ecosystems have unique features that distinguish them from innovation systems in that they have the ability for innovation actors to develop cross-border interaction on a global scale, putting forward requirements for state innovation policy in facilitating the transition from innovation systems to innovation ecosystems [13]. The task of state policy and the role of state entities is to provide means and tools for the development of innovative activity to transform traditional environments of innovation systems into environments of innovative ecosystems of companies [14].

The development of the innovation ecosystem approach had based on the concept of open innovation, the application of which allows expanding the scope of cooperation with external organizations to accelerate the process of developing and entering the market of innovations, as well as reduce the costs of research and development of innovations [15]. Organizational forms of implementing the concept of open innovation in the environment of modern companies and organizations: innovation hubs and coworking spaces, accelerators and incubators, joint development platforms, joint research and development centers, corporate venture funds, alliances and partnerships, innovation platforms [16].

The concept of open innovation has evolved into the concept of open innovation 2.0, which involves cooperation and partnership between government, scientific organizations/universities, enterprises, civil society (quadruple helix) and, as a result, acceleration of the innovation process [19]. Later, the establishment of trusting relationships in coordinated communities, networks and stakeholders had integrated into ecosystem communities. The concept of open innovation 3.0, which involves the creation of innovation ecosystems within the framework of the digital environment and digital transformation [17]. The new concept of open innovation 4.0 involves the application of the

innovation ecosystem and promotion of open innovation, digitalization, improving the policy of creating an open innovation environment in accordance with the “Quadruple Helix” approach, which harmonizes the ecosystem and provides a legal basis for the procurement of innovations and the sharing of risks in research and development [18]. The application of the concept of open innovation involves sourcing ideas, technologies, or solutions from outside the organization and integrating them with internal innovation research and development efforts. The innovation ecosystem approach goes beyond the open innovation approach by creating a network of interconnected participants that create an environment where innovations had continuously developed through joint efforts, shared resources, and agreed-upon goals of the innovation ecosystem [19].

2. Research of existing solutions of the problem

Support for the application of the concept of open innovation from research to commercialization had provided through various European programs, in particular: European Framework Program «Horizon Europe», «European Innovation Council (EIC) programmes, European Institute of Innovation and Technology (EIT) programmes, European Research Council (ERC) programmes, which provide grants for proof of concept and commercial potential studies.

The application of the innovation ecosystem approach had supported through various programmes and initiatives, including the «Horizon Europe European Innovation Ecosystems programme», which focuses on building interconnected and inclusive innovation ecosystems across Europe, supporting the green, digital and social transitions. The Regional Innovation Valleys initiative, which brings together less innovative regions with more innovative ones to address the most pressing challenges facing the EU.

Open innovation and innovation ecosystem programs in Ukraine are implemented mainly through the National Research Foundation of Ukraine (NRFU) and the Innovation Development Fund (Ukrainian Startup Fund — UFS). They support scientific developments, deep-tech startups, and the integration of Ukrainian teams into European innovation networks.

Innovative development, implementation of the concept of open innovation and the innovation ecosystem approach in Ukraine had hampered by military risks, lack of capital, imperfect legislation, weak interaction between science and business. To overcome these challenges, international partnerships are being involved, adaptation to EU standards had implemented, support had provided to defense enterprises, incubators, accelerators, and special economic zones and technology parks had created.

Innovative research, implementation of the concept of open innovation and the innovation ecosystem approach in scientific institutions of the NAS of Ukraine had hampered by an outdated institutional model, chronic underfunding, weak ties with business, and an imperfect regulatory framework for the commercialization of scientific developments. The practical integration of academic institutions into European innovation processes requires deep reforms in the NAS of Ukraine aimed at implementing European principles of open science, the concept of open innovation, the innovation ecosystem approach, and participation in European and international grant programs to attract funding. Departmental programs of the NAS of Ukraine had aimed at solving large-scale scientific and technical problems that meet the priorities of the state, obtaining new scientific knowledge, publications, expert and analytical support that has departmental use. Departmental programs of the NAS implemented by academic institutes, laboratories and are limited in funding mainly from the state budget of Ukraine. Intellectual property rights belong to the state and the NAS of Ukraine institution itself, commercialization is often a secondary goal. Instead, open innovation programs aim to transform scientific ideas into commercial products, services and technologies. They focus on innovative entrepreneurship, the creation of startups and the introduction of innovations into the real sector of the economy, involving cooperation with a wide range of stakeholders: scientists, business representatives, local governments, international organizations, partners and investors. Open innovation programs use mixed funding (grant, investments from private partners) and provide for active technology transfer, licensing of developments and the creation of joint capital.

Thus, one of the important and relevant areas of reform in the NAS of Ukraine is the application of open innovation programs and innovation ecosystem programs.

3. Research results

The activities of scientific institutions of the National Academy of Sciences of Ukraine are aimed at obtaining new knowledge and generalizing existing knowledge about nature, man and society, developing scientific foundations for the scientific and technical, socio-economic and cultural development of the country, comprehensively promoting the application of scientific research results, training highly qualified scientific personnel, and forming a scientific worldview in society. The NAS of Ukraine carries out scientific research within the framework of three main sections, which unite 14 departments and independently determines the topics of research and forms of their organization and conduct [20].

The main organizational forms of implementing innovative activities of scientific institutions of the NAS of Ukraine: scientific and technical programs for the development of branches of the economy; target programs of the NAS of Ukraine; competitions of scientific and technical and investment and innovation projects; agreements, contracts, license agreements with domestic and foreign customers; patents. Important areas of innovation activity of scientific institutions of the NAS of Ukraine are participation: international competitions and European research and innovation programs, joint bilateral scientific competitions with European partners, internship programs, large - scale international collaborations, cooperation with production enterprises, scientific conferences and meetings. Important results of the innovative activities of scientific institutions of the NAS of Ukraine are agreements with domestic customers, contracts with foreign customers, on conducting scientific research, creating and implementing advanced scientific and technical developments, obtaining patents, implementing the tasks of roadmaps for European integration in the field of science and integration into the European Research Area [21].

According to the annual reports submitted by the NAS of Ukraine [22], the main indicators of innovation activity of scientific institutions of the NAS of Ukraine had presented in Table 1.

Table 1 Main indicators of activity of scientific Institutions NAS of Ukraine (2012-2024)

Indicators/Year	2012	2014	2016	2018	2020	2022	2024
Contracts with domestic customers, pieces.	3878	2401	2282	2245	1823	992	1590
Contracts with foreign customers, pieces.	290	195	263	157	131	73	79
Number of implemented scientific and technical developments, pieces.	1676	1166	1150	794	469	372	380
Number of patents obtained, pieces.	722	774	547	580	444	123	85

Data source: [22].

Analysis of the main indicators of activity of scientific institutions of the NAS of Ukraine for 2012-2024 shows that: the number of contracts with domestic customers decreased by 2.43 times, the number of contracts with foreign customers decreased by 3.67 times, the implemented developments decreased by 4.4 times, the number of obtained patents decreased by 8.5 times.

In 2022-2024, a significant decrease in the indicators of innovation activity of scientific institutions of the NAS of Ukraine occurred under the influence of the full-scale invasion of Russian troops into Ukraine, however, scientific institutions managed to adapt to the conditions of war and increase innovation activity within the framework of contracts with domestic customers by 1.6 times from 2022 to 2024 , table 1.

The most innovatively active are five areas: technologies of structural and functional materials - 118 developments (14.3%); medical devices and medical device manufacturing - 117 developments (14.2%); energy and energy efficiency - 116 developments (14.1%); mechanical engineering and device manufacturing - 93 developments (11.3%); information and sensor systems and devices - 89 developments (10.8%), table 2.

Table 2 Advanced scientific and technical developments

of institutions e NAS of Ukraine (2017-2022)

№	Directions	Technological readiness levels, pieces.		Patents of Ukraine, pieces.	Total, pieces.
		TRL2-6	TRL7-9		
1	Agro-industrial complex and ornamental horticulture	54	11	45	65
2	Ecology and environmental protection	56	12	39	68
3	Energy and energy efficiency	84	32	77	116
4	Information technology	48	16	35	64
5	Information and sensor systems and devices	68	21	51	89
6	Mechanical engineering and instrument making	55	38	50	93
7	Medical devices and medical device manufacturing	79	38	87	117
8	Fuel and lubricants and technologies	27	-	17	27
9	Technologies of structural and functional materials	82	36	90	118
10	Technologies and equipment for the detection, evaluation and extraction of minerals	23	16	28	39
11	Food industry	22	6	20	28
Total		598	226	539	824

Data source: own analysis.

It had established that 824 advanced developments of 89 scientific institutions of the NAS of Ukraine had technological readiness of scientific and technological developments at the level: TRL2-6 - 598 (72.6%); TRL7-9 - 226 (27.4%). Intellectual property protection: "Know-how" - 115 (14.0%) developments; patents of Ukraine - 539 (65.4%) developments; international patents - 19 (2.3%) developments. Analysis of advanced scientific and technological developments of scientific institutions of the NAS of Ukraine for 2017-2022 allowed us to distinguish three groups of scientific institutions: 22 scientific institutions with high innovation activity; 30 scientific institutions with medium innovation activity; 37 scientific institutions with low innovation activity.

Scientific institutions of the NAS of Ukraine with high innovation activity presented 478 (58.0%) advanced developments in various priority areas, of which: 364 (44.2%) developments had technological readiness at the TRL2-6 level; 114 (13.8%) developments had technological readiness at the TRL7-9 level. Scientific institutions of the NAS of Ukraine with average innovation activity presented 241 (29.2%) advanced developments in various priority areas, of which: 158 (19.2%) developments had technological readiness at the TRL2-6 level; 83 (10.0%) developments had technological readiness at the TRL7-9 level. Scientific institutions of the NAS of Ukraine with low innovation activity presented 105 (12.7%) advanced developments in various priority areas, of which: 77 (9.3%) developments had technological readiness at the TRL2-6 level; 28 (3.4%) developments had technological readiness at the TRL7-9 level.

Comparison of innovation activity of scientific institutions of the NAS of Ukraine for 2017-2022 had presented in table 3.

Table 3 Comparison of innovation activity of scientific institutions of the NAS of Ukraine (2017-2022)

Level of innovation activity	Number of NASU institutions, pieces.	Number of scientific and technological developments at the levels TRL2- TRL6 per institution, pieces.	Number of scientific and technological developments at the level of TRL7- TRL9 per institution, pieces.	Number of scientific and technological developments per institution, pieces.	Number of scientific and technological developments per institution per year, pieces.
High innovative activity	22	16,5	5,2	21,7	4,3
Average innovation activity	30	5,3	2,8	8,1	1,6
Low innovation activity	37	2,1	0,76	2,86	0,6

Data source: own analysis.

Scientific institutions of the National Academy of Sciences of Ukraine with high innovation activity demonstrate excellent results of innovation activity due to the implementation of the following key success factors: Efficiency (Higher number of scientific and technological developments per institution per year). Financing (Active participation in international, European, national programs, agreements with domestic customers and contracts with foreign customers). Partnership (Increasing number of cooperation agreements and membership in associations/consortia). Internationalization (Direct interaction with foreign scientific centers and universities. Creation of offices to support submission of applications and building consortia for participation in European research and innovation funding programs). Marketing (Regular presentation of scientific results and technologies at exhibitions of all levels). Analytics (Mandatory creation of feasibility studies and preparation of commercialization projects for scientific and technological developments that have reached TRL 4-5).

In 2024, the departmental research topics of the NAS of Ukraine accounted for 75.6% of the total number of research topics of the NAS of Ukraine. Fundamental research accounted for -56.7%, applied research accounted for -18.9%, program-targeted and competitive topics -16.2%, state topics -8.2%. This indicates that the overwhelming number of research topics had focused on fundamental research programs, which have a traditional organization of scientific projects, within which, as a rule, individual research groups of a scientific institution independently conduct research to achieve technological readiness of developments to the TRL3 level.

Within the framework of traditional applied research projects and program-targeted competitive topics, which usually have a traditional organization of projects in which individual research groups of a scientific institution independently bring scientific and technical developments to the level of technological readiness TRL6. Within the framework of agreements with domestic customers and contracts with foreign customers, scientific and technical developments had brought to the level of technological readiness TRL7-TRL9.

The traditional organization of scientific projects within the framework of departmental topics of NASU programs, as a rule, applies the concept of closed innovations within the framework of linear innovation process, which assumes that individual scientific research groups of a scientific institution try independently go through all stages from idea to implementation, which artificially inhibits commercialization at the market.

However, the organization of scientific projects within the framework of the open innovation program expands this focus by involving a wide range of partners (government institutions, enterprises, universities, spin-off companies, startups, public organizations, etc.). The introduction of the organization of scientific projects within the framework of a new type of programs - open

innovation programs - will allow changing the approaches to program-targeted financing and giving priority to grants implemented in consortia.

The main stages of the transition from the application of departmental programs projects to open innovation programs projects, which focus on the creation and implementation of scientific and technical developments in accordance with the achievement of the TRL level. Open innovation programs provide support for the creation and implementation of advanced scientific and technological developments at all stages of the open innovation process within the framework, for example: joint research program, joint development program, co-scaling program.

Joint research program is aimed at supporting projects that substantiate the scientific principles of developing new breakthrough technologies and must demonstrate a positive assessment of scientific principles and concepts that open up new scientific and market opportunities.

Joint development program - aimed at supporting projects that conduct joint experimental research in scientific laboratories and centers to confirm the operability of prototypes ("deep technologies") in laboratory conditions, a working environment, and demonstrate a prototype product in the environment.

Co-scaling program - aimed at supporting projects that focus on jointly supporting the growth of breakthrough innovative scientific and technical developments within innovative enterprises.

Existing advanced scientific and technical developments of the NAS of Ukraine institutions, which have stopped at different stages of development and have different levels of technological readiness (TRL), which achieved within the framework of departmental programs projects, can be included in the projects of open innovation programs.

Open innovation programs should be based on best European practices and approaches to project progress assessment and technology readiness level (TRL) assessment [23], in particular within the framework of the programs: European Innovation Council (EIC), European Institute of Innovation and Technology (EIT), European Research Council (ERC).

To create an environment for the systematic creation and implementation of advanced scientific and technological developments using the concept of open innovation, innovation ecosystem programs can be introduced that involve the state, scientific institutions, business and society in partnerships. Innovation ecosystem programs should be built in accordance with the principles of forming the Horizon Europe "European Innovation Ecosystems" programs.

The purpose of these programs is to transition from isolated activities of scientific institutions to network interaction of scientific institutions within the framework of four-way spiral models (science, business, state, civil society) and systemic support for the creation and implementation of advanced scientific and technical developments and the development of innovation ecosystems within the NAS of Ukraine. Innovation ecosystem programs according to the main stages of the innovation ecosystem life cycle may include program for creating innovation partnerships, joint pilot activities program, joint acceleration program, interconnected ecosystem programs.

The innovative partnerships program is to stimulate the projects of the creation of connections and the involvement of various participants in the innovation ecosystem of the four-way spiral: scientific institutions of the NAS of Ukraine, universities, innovation centers, investors, clusters, business associations, industrial enterprises, startups, spin-off companies, SMEs, civil society organizations, public and private buyers of innovative solutions. Within the framework of these programs, projects identify trends, needs, market opportunities, test existing innovative solutions, form requirements for the generation of new ideas, products, technologies, key participants of the innovation ecosystem.

The joint pilot activity program can stimulate the projects of the developing and implementing joint action plans of participants in the four-way spiral innovation ecosystem aimed at consolidating and specializing all participants in the innovation ecosystem. Within the framework of these programs, joint piloting projects can be implemented around various technological areas, including those related to research infrastructures that contribute to the development of national and European scientific cooperation and the commercialization of new knowledge.

The joint acceleration program can stimulate the projects of the supporting projects at the regional and interregional level, covering a wide range of experienced innovative participants in the

four-way helix innovation ecosystem. Including related pan-European research infrastructures, which can contribute to expanding the scope of applications, improving value propositions, reducing the time to market for advanced scientific and technological developments, increasing the volume of innovation ecosystem activities, and improving knowledge transfer in the European Research Area.

The interconnected ecosystems programme can stimulate the projects of the cross-border agreements that bring together international, national and academic programmes that contribute to the formation and development of transnational innovation ecosystems of the four-way helix. The use of pan-European research infrastructures and innovation procurement, which accelerates the creation, implementation and scaling of breakthrough cutting-edge scientific and technological developments that address socio-economic challenges.

4.Conclusions.

Analysis of the main indicators of activity of scientific institutions of the NAS of Ukraine for 2012-2024 shows that: the number of contracts with domestic customers decreased by 2.43 times, the number of contracts with foreign customers decreased by 3.67 times, the implemented developments decreased by 4.4 times, the number of obtained patents decreased by 8.5 times.

For 2017-2022 the most innovatively active are five areas: technologies of structural and functional materials; medical devices and medical instrument-making; energy and energy efficiency; mechanical engineering and instrument-making; information and sensor systems and devices.

Based on the assessment of 824 advanced scientific and technical developments of 89 scientific institutions of the NAS of Ukraine, it had found that despite the high competitiveness of the obtained scientific results, a significant part of knowledge and scientific and technical developments remains uncommercialized and unused in real sectors of the economy.

It was found that traditional projects of the departmental programs of the NAS of Ukraine, as a rule, apply the concept of closed innovations within the framework of a linear innovation process, which assumes that individual scientific and research groups of a scientific institution try to independently go through all stages from idea to implementation, which artificially inhibits commercialization and creates a gap between science and the market.

The scientific institutions of the NAS of Ukraine had differentiated by the level of efficiency of creating scientific and technical developments into three groups: with high, medium and low innovative activity. A cause-and-effect relationship had revealed, when scientific institutions of the NAS of Ukraine with high innovative activity generate and implement many times more scientific and technical developments precisely due to participation in European programs and initiatives based on the principles of applying the concept of open innovation and the approach of innovation ecosystems.

Based on the analysis of the theoretical and methodological foundations of the development of the concept of open innovation and the approach of innovation ecosystems, it had established that the transformation of traditional innovation systems into innovation ecosystems is due to the transition from the application of the concept of closed innovation to the concept of open innovation. This has fundamentally changed the philosophy of creating and implementing innovative developments, when companies and organizations are no longer limited to internal resources, but actively attract external sources of knowledge and capital through open innovation processes. The close relationship and complementarity of the concept of open innovation and the ecosystem approach, as basic components of the approach of innovation ecosystems, which form a favorable environment for the creation and implementation of scientific and technical developments, had proven.

A conceptual approach to the formation of open innovation programs and innovation ecosystem programs had proposed, which synchronized with the principles and architecture of European programs. The proposed approach allows overcoming the limitations of the concept of closed innovations within the framework of the linear innovation process. To provide end-to-end support for scientific developments at all stages of the open innovation process - from fundamental research to implementation, minimizing the risks of scientific institutions of the NAS of Ukraine independently bringing scientific and technical developments to market entry.

Using the proposed approach allows to apply the "Quadruple Helix" approach with a focus on pan-European research infrastructures, systematic to accelerate the creation/implementation of the advanced science developments of scientific institutions of the NAS of Ukraine and significantly increase the level of involvement and integration of scientific institutions of the NAS of Ukraine into the European Research Area (ERA).

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