STRUCTURING AND DETERMINING THE INFLUENCE OF STAKEHOLDERS ON THE INNOVATION ECOSYSTEM

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Abstract

In this paper, criteria for the distribution of stakeholders of the innovation ecosystem (IE), such as subsystems, functional features and positions, are formed. Stakeholder matrices and maps have been constructed for monitoring and identifying trends in changes in the rank of stakeholders in the innovation ecosystem. According to the conducted calculations, in addition to quantitative calculations, their qualitative assessments were provided according to linguistic sets. In the process of research, the method of constructing membership functions of discrete fuzzy sets, as cognitive modeling, was used to determine the influence of cause-and-effect relationships. The elements of the matrix of mutual influences of the cognitive map were expertly formed in the modeling process. The purpose of the paper is to identify the stakeholders of the innovation ecosystem, structure them by subsystem categories, sphere and level of influence, to model the interaction of stakeholders within the innovation ecosystem. Understanding the systemic roles and interactions of stakeholders is critical to gaining a more accurate and detailed view of their contributions. A purposeful approach to building an innovative ecosystem allows you to form stakeholders to ensure their effective interaction.

Keywords: Stakeholder, Innovation Networks, Cognitive Modeling, Education, Science, Business

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1. INTRODUCTION

Over the past few years, countries around the world have faced significant economic challenges and changes in the context of the effects of the global pandemic, and Russia's invasion and military aggression in Ukraine. All these challenges raised new questions about the future of *innovation ecosystems* (IE), the interaction between stakeholders of innovation activity and the challenges they need to overcome to transform and become sustainable structures.

The innovation ecosystem is distinguished by its versatility and integration based on the networks of the state, business and research environment using organisational, regulatory, educational and

financial resources and the introduction of a knowledge transfer mechanism for the purpose of transformation into innovative products. We reviewed studies that have identified the flexibility between innovation ecosystem models and open innovation (OI) approaches and considered their impact on new businesses. In particular, models of innovation ecosystems were categorized into innovation ecosystems according to the ability to access resources (Zhang et al., 2023).

The actors of the innovation ecosystem are all members engaged in the formation of innovations (students, universities, businesses, entrepreneurs, experts, individual owners, agencies, scientific research facilities, funders, organizations, investors, funds, and companies), which leads to co-location with growing exchange networks and further network effects. Networked innovation can have a significant impact on profits, efficiency, and growth, as it allows for the use of best practices, reductions in redundancy, and time savings. The present study, and the works of Jonas et al. (2018), Linåker et al. (2016) and Bettanti et al. (2022) present the study of innovation ecosystems through the prism of the stakeholder model, as well as Randhawa et al.'s (2020) research demonstrating the development of transformational strategies for public innovation that involves a comprehensive transformation of internal and external relations with stakeholders.

Innovations are provided by joint activity thanks to the forming network or cluster interaction, as well as orientation to common values and interests. The innovative economy is based on a complex network of subjects, which relies on market competition, incentives for investors, and on the education system, which is the educational base and determines the prospects for further research. The support of this network primarily requires orientation to the interaction of network elements. The effectiveness of the innovation economy is also related to the formation of research, development and production networks, which contributed to the significant growth of numerous leading global innovation clusters. The network idea considers the state and the economy as elements in a system of changing networks. A well-developed structure of innovation networks and clusters provides access to research, information, development and networks, and efficient technology progress and education facilitates the rapid expansion of technologies, including their further introduction to the market. According to the study by Cai (2022), the neo-Triple Helix model of innovation ecosystems can be represented by integrating the triple, quadruple, and quintuple helix models. We suggest that the model of innovation ecosystems should be viewed through the interaction between innovation, social structures and the natural environment in dynamics, which include two levels of the triple helix (or triad) interactions: 1) university, industry and government at the *systemic level*, and 2) innovation processes, financing and environment at the *functional level*.

Innovation networks emerge as a result of organized strategies and the involvement of stakeholders. Through the various components of the innovation network, such as innovation policy, the stimulation of innovative activities of organizations and the development of stakeholder interaction models, the transition to the innovation economy is supported, offering platforms for learning and knowledge sharing, providing recommendations for capacity building. The study by Christos et al. (2022) also identified the availability of financing possibilities, communication with stakeholders, business training, background of start-ups, accelerator services and coaching as the major factors influencing the successful progress of start-ups.

The advantages of innovation networks are exchange and subsequent network effects in the structure of stakeholders. Partnerships and cooperation between organizations, business actors, the public sector, consumers and local communities, as well as other stakeholders, are necessary for the transition to the innovation economy. Stakeholders have an important role to play in creating the conditions for a strong innovation economy, and this work will require significant consultation and coordination, protection and value to give people and organizations the incentive to expand innovation networks.

Further research is needed to identify opportunities and generate ideas by leveraging knowledge, skills and experience for the effective development of business ideas and innovative projects. Furthermore, from the perspective of the innovation system, the interactions between students, academics, and companies have rarely been studied, which creates a relational dimension of the enabling environment and a comprehensive view of cooperation between stakeholders. In this article, the authors address these issues using cognitive modeling combined with systems analysis to create a process framework for innovation system stakeholder collaboration.

The purpose of the paper is to identify the stakeholders of the innovation ecosystem, structure them by subsystem categories, sphere of influence, and level of influence, and model the interaction of stakeholders within the innovation ecosystem. The network analysis proved valuable in understanding how to create insights regarding historical, current, and potential new power structures and stakeholder relationships. There have been indications of how such features are impacted in the way stakeholders communicate among themselves. The development of the innovation network and the implementation of innovations require further tools to establish an effective dialogue on the promotion of innovative technologies and the principles of sustainable development. Further research is needed to develop a strategy for engaging and cooperating with stakeholders.

The influence of stakeholders in the innovation system on the formation of an innovation network was determined. The study summarizes the theories of stakeholders in accordance with the innovative development of society and structures them according to various criteria. The structuring of stakeholders of the innovation ecosystem by the categories of subsystem, functional feature and position is substantiated. The system parameters of the cognitive model are evaluated and the scope and criteria for the system parameters of the cognitive model of the impact of innovation ecosystem stakeholders are determined.

The structure of this paper is as follows. Section 2 reviews the relevant survey of the research paper on the structural relationships between the innovation ecosystem and its stakeholders. Section 3 analyses the methodology that has been used to conduct empirical research on structuring and determining the influence of stakeholders on the innovation ecosystem. Section 4 implements modeling the interaction of stakeholders of the innovation ecosystem that has the following fundamental provisions:

1. To form a structure of stakeholders, where the main task is to determine the structuring criteria and the affiliation of subjects according to certain characteristics.

2. Determine the directions and levels of influence of stakeholders as a complex organizational and technical system consisting of elements and their relationships.

Section 5 presents conclusions, identifies future research directions based on the results of the current study, and presents some limitations of this study.

2. LITERATURE REVIEW

Some aspects of structuring and determining stakeholders in the innovation ecosystem are considered in the studies of many authors. Nwanji and Howell (2007) examine the impact of shareholding and stakeholder models on the achievement of business goals. The study is aimed at business management using a systematic approach to interaction with stakeholders. Kraus et al. (2020) summarize the characteristic features of the impact of research and innovation on the digitalization of enterprises. The authors define the forms of relations involving public and private stakeholders by forming a cluster based on an innovation hub and substantiate measures to combine the potential of scientific research and innovative developments directly with industry.

In contrast to others, Matozza and D'Amico (2020) argue that socio-psychological factors influence collaboration between stakeholders, which promotes innovation. A combination of different corporate governance models can enable management to meet the needs of stakeholder groups. In turn, Bertin and Mavoori (2022) investigate the elements of human and social capital of startups that influence research and development (R&D) activities in collaboration with businesses.

Malik and Yadav (2020) review corporate sustainability ratings for academic research stakeholders. Sieg et al. (2023) analyse academic entrepreneurship in terms of innovation and sustainable development. The authors identify and evaluates innovation support programs implemented by universities. The necessity of certain changes and improvements in order to facilitate cooperation between academia and business is proven.

Reypens et al.'s (2019) study of a multi-stakeholder innovation network was based on the premise that interacting with a large number and diversity of stakeholders creates new challenges for the network. The authors also explore three different stakeholder-level processes for capturing value. Abdelfattah et al. (2023) identified the key factors that influence human resources in e-entrepreneurship and innovation. They assessed opportunities and entrepreneurial education and determined the relationship between entrepreneurial role models and education in promoting the growth of new business enterprises.

Singh and Rahman (2022) examine multi-stakeholder partnerships, which can be described as a pragmatic model of stakeholder engagement. Kolodiziev et al. (2023) identify significant indicators of quality and social responsibility in the provision of higher education, according to which territories are classified by the actual level of social responsibility in accordance with the location of universities. Two models have been developed: 1) clustering the quality of higher education services under martial law, and 2) optimizing higher education services by the level of social responsibility.

2.1. Stakeholder theory

The formation of an innovative economy has become a priority in the process of increasing the competitiveness and prosperity of the countries of the world. The research of the literature shows the development of modern instruments for the generation of innovations, in view of their branching and bottom-up nature. Practitioners and scientists offered different views on the question of which stakeholders are needed to build an innovation ecosystem (Table 1).

Table 1. The development of the theory of stakeholders in accordance with the innovative development of society

Authors/source	*Concept*	*Stakeholders*	*Orientation*
Möller and Halinen (1999)	Bilateral relationship ("Dyad")	Business–Government	• Access to resources and/or customers. • Time perspective.
Etzkowitz and Leydesdorff (2000)	Concepts of the triad "Triple Helix"	Business–Government–University (entrepreneurial university)	• Knowledge economy. • Techno-centric.
Carayannis and Rakhmatullin (2014)	Quadruple Innovation Helix	Business–Government–University–Society	• Public and civil society based on media and culture. • Society of knowledge, democracy of knowledge. • Human-centric.
Carayannis and Campbell (2021)	Quintuple Innovation Helix	Business–Government–University–Society–Environment	• The natural environment of society. • Social ecology. • Balanced techno- and human-centric.

Source: Developed by the authors.

Customized solutions with extensive stakeholder engagement are an important characteristic of impact innovation. It allows for a more participative, affordable, and sustainable innovation ecosystem that is founded on communication and refers to the beliefs of the community. Moreover, they emphasize the significance of skills in creating well-being and overall standards of quality of life.

2.2. Structuring of stakeholders

Collaborations across sectors or multistakeholder groups can considerably promote the transition to sustainable development. New forms, models and networks of collaboration are emerging, generating a certain value that can ultimately lead to transformation.

Also, in addition to the main stakeholders, those who play a supporting, although sometimes secondary, role can be considered. This may include actors that may also play a hybrid role, where they are both powerful contributors to the innovation ecosystem and may represent distinct stakeholder subsystems. Table 2 presents different options for structuring stakeholders by type of criteria.

The below theories (Table 2) offer different points of view of the authors regarding stakeholders, according to the content and influence on the activity. These processes are dynamic, so stakeholders can change according to the operating conditions. The considered theories are more universal and involve ignoring the specifics, scope and interest in the activity.

Table 2. Structuring of stakeholders according to various criteria

Author/theory	*Criteria*	*Types*
Freeman (1984)	—	• Owners and shareholders; • Buyers of products (consumers); • Consumers of services; • Suppliers of various types of resources (suppliers and distributors); • Employees of the enterprise; • Local community; • Various broad social groups; • The state (society in general); • Mass media; business partners; • Future and past generations, etc.
Sternberg (1997)	Materiality, immediacy, legitimacy	—
Newbould and Luffman (1978)	Functional characteristic	• Influence groups financing the enterprise (for example, shareholders); • Financial groups of influence; • Managers who run the enterprise; • Employees and employees who work directly at the enterprise; • (at least that part of them that is interested in achieving its goals); • Economic groups of influence (who are interested in achieving business goals); • Economic partners.
Mendelow (1981)	The degree of interests and power: • interests; • desire to influence and power; • the ability to influence.	The power of stakeholders is determined by: • ability; • desire; • to influence the enterprise.
Savage et al. (1991)	Level of threat and intensity of interaction	• Supporting; • Mixed; • Not supportive marginal.
Mitchell et al. (1997)	Taking into account three factors: • legality; • urgency; • power/significance	• Sleeping, predominant, final, • Discretionary, dangerous, • Dependent, exacting.
Clarkson (1995)	Develops a classification of management strategies, which he calls the RDAP (reactive, defensive, accommodative and proactive) scale	• Invested stakeholder; • Employee (main); • Observer (secondary); • Third stakeholder.

Source: Developed by the authors.

However, in the process of improving the innovation economy, an essential aspect is the interaction of stakeholders, which affects the degree of novelty of the innovation being implemented, the safety of the stages and procedures of innovation implementation, forms relationships between the participants in the implementation of innovation, and ensures a balance of interests of the parties to the innovation process. Therefore, it is advisable to determine the structure of the stakeholders of the innovation ecosystem and to model their interaction using the fuzzy-set qualitative comparative analysis (Fs/QCA) with the involvement of expert evaluations for the evaluation of such characteristics.

3. RESEARCH METHODOLOGY

The proposed approach, unlike the existing ones, will take into account the multidimensionality and dynamics of stakeholder characteristics and will form a mathematical basis for multidimensional stakeholder analysis. Existing methods of stakeholder analysis will be used in the future to create instrumental tools for managing stakeholders of the innovation ecosystem.

In the study of Al-Mannaei et al. (2016), one linear regression model was built to study the relationship between corporate governance and innovation. It was determined that there is no relationship between corporate governance and innovation in the selected companies, as innovation is weak. The study by Singh and Rahman (2022) was based on the publication of sustainability reports by companies according to the standards included in the content analysis for data collection. Multiple linear regression was used to analyze secondary data to establish an empirical relationship between corporate social responsibility implementation and company performance. The results of this study showed that firms' adoption of sustainable development goals (SDGs) is significantly and positively related to their financial, environmental, and social performance.

An effective tool for modeling stakeholder interaction is a systematic method of stakeholder mapping to support co-creation, which has also been used in studies of Zingraff-Hamed et al. (2020) and Pinto et al. (2021) discuss the construction of a social innovation ecosystem and present a research approach to mapping. The main purpose of cognitive modeling is to shape and refine the concept of the investigated entity, which is interpreted as a loosely organized complex composed of separate internal and external elements, subsystems that communicate with each other, based on a structural scheme of mutually supportive linkages (Axelrod, 1976). The main task that is solved within the framework of the cognitive approach is the task of forecasting and the task of choosing alternative management strategies (Kosko, 1993). Cognitive models allow the analysis of the studied situation by studying the structure of mutual influences of the concepts of the cognitive map and dynamic analysis, which consists of the generation of possible scenarios of its development (Bertassini et al., 2021). The cognitive approach is founded on the establishment and research of cognitive maps that, in a general meaning, are a conceptual, symbolic overview of the elements of a system's activity connected with a relevant issue (Savchuk et al., 2009; Ladanyuk et al., 2014). Camargo et al. (2021) propose a new methodology based on the *Kano model* and require a compromise methodology for a multi-stakeholder ecosystem in the early stages of design that allows for the identification and anticipation of stakeholder ecosystem needs.

Modeling the interaction of stakeholders of the innovation ecosystem makes it possible to improve the automated system of management of innovation activity based on a cognitive approach, which will provide an opportunity to comprehensively evaluate the indicators of innovation activity with consideration of external and internal factors and to form reasonable strategic management directions in conditions of uncertainty.

3.1. Methodology and research framework of the cognitive modeling

An innovative ecosystem is characterized by significant uncertainty of the elements that make up its composition (factors), and it is impossible to obtain its exact mathematical model for modeling the development of such a system. As for existing models, methods of identification and analysis of stakeholders, most of them are based on the evaluation of certain criteria, and the evaluation process itself is mainly carried out by an expert method. In order to apply the findings of such surveys in practice, it is essential to increase the variety of indicators and conduct a multidimensional stakeholder assessment.

Specific techniques for obtaining and evaluating specialist data can be used to minimize the level of dependency and maximize the reliability and substantiation of conclusions. This is achieved by dividing the overall task of determining the effect of correlations into a series of more basic subsets. In general, the influence of causality can be determined based on the analysis of continuously variable membership functions of discrete fuzzy sets, namely *cognitive modeling*.

The cognitive modeling methodology is focused on simulating the opinions of professionals regarding the situation and consists of 1) a procedure for positioning the structure of the process; 2) a representation scheme of the specialist's skills in the way of a cognitive map; 3) techniques for evaluating the position.

When managing in conditions of incomplete and inaccurate information, as well as when determining various options for the functioning of elements of the system and the environment, fuzzy cognitive maps (FCMs) are used, where the set of connections between concepts is presented in the form of numerical values of the degrees of causality of such connections. Analytical processing methods are applied to the constructed map, focused on studying the structure of the system and obtaining forecasts of its behavior under various controlling influences.

The process of cognitive modeling begins with the formation by experts of a list of concepts most significant for this task.

The following elements of the interaction matrix were expertly selected:

1. Affiliation, which describes the group to which the stakeholder of the innovation ecosystem belongs and represents.
2. Two fuzzy sets associated with concepts:
   - many concepts affecting this concept;
   - the set of concepts that are affected by it.

3.2. Study estimations

Using the obtained fuzzy cognitive map, a matrix of concepts' interactions is formed, followed by the study of the map's performance and reliability. Its estimated systemic characteristics are *consonances* and *dissonances*. From the matrix *Z*, it is possible to calculate the described main indicators of FCMs (Hester, 2015) (see Table 3).

4. RESEARCH RESULTS AND DISCUSSION

4.1. Structuring of the innovation ecosystem`s stakeholders

The innovation economy is an economy founded on education, new achievements in science and high intellectual capital. Knowledge, business, innovation, technology and their cooperation are the key drivers

of economic growth in an innovation economy. At present, the evolution of the innovation economy is hampered due to the problems of science funding, modernization of the material and technical base of scientific laboratories and universities, and the challenges of preparing innovative experts. Obviously, the backlog of research and technical facilities for the learning experience, its collaboration with the industry, the lack of innovative efforts by companies in this direction, and their poor financial capacity have a negative effect. Therefore, it is appropriate to identify three key subsystems of stakeholders, which are crucial for the success of most efforts to create an innovative ecosystem, as well as for the further growth and acceleration of innovative entrepreneurship in the ecosystem, namely: 1) the education subsystem, 2) the science subsystem, and 3) the business subsystem (Table 4).

Table 3. The main system indicators of Silov's fuzzy cognitive maps

Indicator	*Calculation*
Influence (influence) of the *i*-th concept on the *j*-th (influence means the dominant influence between concepts)	$p_{ij} = sign\,(z_{ij} + z^{-}_{ij}) \max(\lvert z_{ij}\rvert, \lvert z^{-}_{ij}\rvert)$, $(\lvert z_{ij}\rvert \neq \lvert z^{-}_{ij}\rvert)$ z_{ij} – the strength of the positive influence of the *i*-th concept on the *j*-th, z^{-}_{ij} – the strength of the negative impact of the *i*-th concept on the *j*-th.
Mutual (joint) positive influence	$\overleftrightarrow{p_{ij}} = \overleftrightarrow{p_{ji}} = S\,(z_{ij,}z_{ji})$ S – corresponding S-norm (maximum operation).
Mutual (joint) negative influence	$\overleftrightarrow{n_{ij}} = \overleftrightarrow{n_{ji}} = -S\,(z^{-}_{ij,}z^{-}_{ji})$
The consonance of the influence of the *i*-th concept on the *j*-th (expresses the degree of trust in the sign and the power of influence: the higher the consonance, the more convincing the opinion)	$c_{ij} = \dfrac{\lvert z_{ij} + z^{-}_{ij}\rvert}{\lvert z_{ij}\rvert + \lvert z^{-}_{ij}\rvert}$
Consonance of the mutual influence of the *i*-th and *j*-th concepts	$\overleftrightarrow{C}_{ij} = \overleftrightarrow{C}_{ji} = \dfrac{\lvert (z_{ij} + z_{ji}) + (z^{-}_{ij} + z^{-}_{ij})\rvert}{\lvert (z_{ij} + z_{ji})\rvert + \lvert (z^{-}_{ij} + z^{-}_{ij})\rvert}$
Influence (influence) of the *i*-th concept on the system	$P_i^{\rightarrow} = \dfrac{1}{n}\sum_{j=1}^{n} p_{ij}$
The influence (influence) of the system on the *j*-th concept	$P_j^{\leftarrow} = \dfrac{1}{n}\sum_{i=1}^{n} p_{ij}$
Consonance of the influence of the *i*-th concept on the system	$C_i^{\rightarrow} = \dfrac{1}{n}\sum_{j=1}^{n} c_{ij}$
The consonance of the system's influence on the *j*-th concept	$C_j^{\leftarrow} = \dfrac{1}{n}\sum_{i=1}^{n} c_{ij}$

Source: Generalized by the authors based on Hester (2015).

Table 4. Stakeholders of the innovation ecosystem by subsystem categories, functional features and position

Position	*Functional feature*	*Subsystem*		
		Education	*Scientific*	*Business*
(1)	*(2)*	*(3)*	*(4)*	*(5)*
Concepts of internal state — direct influence	Innovating (*I*)	Educational institution (I_{IE})	Scientific institution (I_{IS})	Business entity (I_{IB})
		Employee (I_{IESB})		
	Financing (*F*)	Founder/Manager (F_{ISB})		Shareholder (F_{IB1})
		Student (F_{IE})		Consumer (F_{IB2})
				Investor/Business angel (F_{IB3})
		Financial/Credit institution (F_{IESB})		
	Providing (*P*)			Business association (corporation/consortium/concern) (P_{IB})
		Science/Innovation park/Technology park/Technopolis (P_{IESB})		
		Coworking, educational and creative hubs (P_{IES})		
			Business park/Center/Incubator/Science/Technology center/ Technology transfer center/Consulting center (P_{ISB})	
Concepts of the macroenvironment (External environment) — indirect influence	Innovating (*I*)	State authorities/Local self-government bodies (I_{EESB})		
				Provider (I_{EB})
		Partner (I_{EESB1})		
		Government institution/State institution (I_{EESB})		
	Financing (*F*)		National Research Fund of Ukraine (F_{ES})	Business support funds (F_{EB})
		Grant foundation (F_{EES})		
		Charitable foundation (F_{EESB})		
	Providing (*P*)	Mass media (P_{EESB1})		
		Public association/Organization/Non-governmental organization (P_{EESB2})		
			International/Scientific and technical alliance (P_{ESB})	
				Cluster/Transnational corporation/Financial/industrial group/International group of companies (P_{EB})

Source: Authors' elaboration.

The main function of the innovation ecosystem is to ensure network interaction of the structural elements of the innovation economy. They provide services in accordance with the network profile (educational, financial, consulting, marketing, information and communication, legal, etc.) within the framework of innovation activities within the business, educational and scientific sectors. Dissemination of various information in various forms, provision of information, analytical and organizational services to innovation participants is possible through the creation of a scientific sector, establishment of permanent contacts between them and pooling of resource flows. In the structure of the innovation ecosystem, we propose to highlight the following functional characteristics of stakeholders (column 2, Table 4):

- *Innovating* (*I*) (organizations carrying out innovative activities in the development and production of innovative, scientific, technical and intellectual products);
- *Providing* (*P*) (provision of material resources, communication between all stakeholders of the innovation network, creation and maintenance of the information collection mechanism; legal, marketing, information support, etc.);
- *Financing* (*F*) (organizations that provide financial support for the innovation network, carry out calculations and distribute cash flows, use funds for the development of the innovation network).

An innovation ecosystem is characterized by a network of connected and interdependent stakeholders that have low connectivity (from formal to informal and from weak to strong). Such ecosystems also sometimes have a hierarchical structure that denotes different power dynamics and differentiated resources. Successful innovation ecosystems have some form of social cohesion that guides and is driven by collective action to ensure robustness, a tighter network, and greater sharing of resources. Such networks create a range of formal and informal norms and institutional practices that support the types of resource sharing that are the lifeblood of innovation ecosystems. In general, stakeholders in education, science and business can be divided into two concepts, according to their position in decision-making (column 1, Table 4):

- concepts of internal state — direct influence;
- concepts of the macroenvironment — mediated influence.

The proposed categories of stakeholders were divided by subsystems (education, science and business), positions in the decision-making process (direct and indirect influence) and functional features (innovative, financial and providing). The association of some categories of stakeholders is related to the exchange of values, freeing them from financial compensation for knowledge, products or services. The analysis of the matrix of stakeholders makes it possible to identify areas and new forms of interaction with stakeholders, to determine additional measures to improve efficiency and achieve a state of mutual satisfaction.

The innovation economy poses significant challenges and new requirements for training and learning that should expand to cover the new requirements for retraining the working power, as is the need to quickly update academic programs and fundamental business and economic concepts for new applicants.

Universities provide a range of diverse activities and ideas for the innovation ecosystem and must play a multifaceted role in providing new science ideas, technical and scientific training, entrepreneurial education, etc. Universities have a number of different touch points with the innovation ecosystem. In addition to engaging with diverse stakeholders within a single university, engaging with multiple universities in an ecosystem can also be critical, especially when they differ in their comparative advantage in research, their focus on education, or their engagement with corporations for different purposes. Universities should take an intensive position in establishing and forecasting trends, as opposed to simply reacting to these. Higher education institutions and educational service providers are creating a strong foundation that can help to become a leading international center for high technology and innovation. A key driver of a sustainable economic model is the possibility of establishing an ecosystem of lifelong learning and research.

Scientific institutions make the main contribution. Scientific institutions and research centers are an important component of the innovation ecosystem. These include the National Academy of Sciences of Ukraine, research centers and business support organizations, which provide a number of business services and help establish connections between entrepreneurs, investors and business angels, and organize numerous public events. Scientific institutions often have no connection with the external economic and business environment, and they also lack international contacts. The role of science parks in the economy should be enhanced by improving legislation, popularizing them, forming ratings, etc. This will make it possible to increase the trust between science (innovation) and business, obtain a higher quality technologically ready innovative product; most projects will be implemented and commercialized, and accordingly, the income (benefit) of stakeholders will increase.

Given the central role of *businesses* in the innovation ecosystem, their participation is critical to building the ecosystem. Without this element, efforts to build an innovation ecosystem can go unsupported. Business structures are directly involved in the introduction of innovations in production and the implementation of an innovative product but are significantly behind in the development and implementation of innovations. As a result of improving the efficiency of innovative activities, they will be able to gain new sales markets, increase profits, expand production, etc. Companies can increase their value by creating new ideas that can be developed into products, services and business models. Businesses can take different approaches to network innovation. Some may purchase information from other stakeholder partners or obtain it through partnerships, alliances or licensing. Others outsource their R&D depending on their willingness to give up some degree of secrecy. Other approaches include joint ventures, alliances, joint development, contract R&D, direct procurement, licensing, investment in universities, etc.

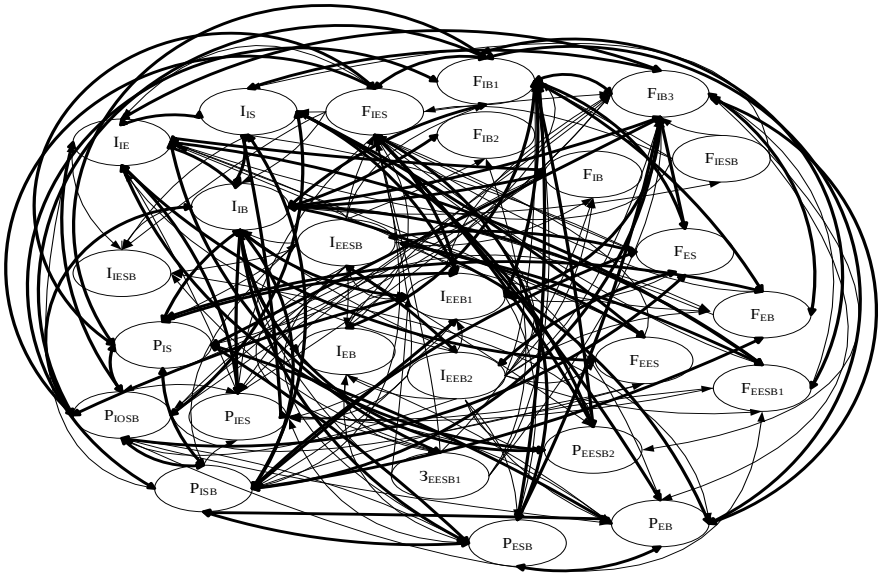
Important elements of the innovative economy are *business parks/centers/incubators*, which are created to support non-technological small entrepreneurship, or act as part of a technology park and be oriented to work in areas of high technology, that is, support of small innovative entrepreneurship in the scientific and technical sphere. The main goal of business incubators in an interactive process is to provide assistance to new companies at the stage of their organization and formation, to inspire people to organize their own business, to create conditions that contribute to their support in the development of innovative products.

Having identified the three main subsystems of stakeholders in the innovation ecosystem, it is important to identify a number of actors who can be involved in the creation and play a role in a complex innovation ecosystem. In one way or another, they belong to the three main subsystems of stakeholders and can be included in it, depending on specific circumstances (see Table 4).

4.2. Cognitive model for stakeholders of the innovative ecosystem

Using the acquired data, a cognitive matrix is generated, comprising assessments of the influence intensity averaged over the opinions of all experts, on the basis of which a FCM is constructed. Constructing a stakeholder matrix or map is an applied approach to grouping and use as a starting base for monitoring and identifying trends in changes in the rank of stakeholders in the innovation ecosystem. Figure 1 presents a visualization of the location of influence between stakeholders of the innovation ecosystem.

Figure 1. Symbolic orthography of a cognitive map of the influence of stakeholders in an innovation ecosystem by categories of subsystems, functional features and positions



Positioning, subsystem and functional features determine the level and nature of influence, which determines the direction and tools of management of innovative activity. Due to the visibility of the relationship between stakeholders, it is possible to determine the level of influence between individual stakeholders. This allows us to formulate the policy of the innovation ecosystem, namely the goal and task of involving certain groups of stakeholders, levels and methods of their participation, and distribution of roles and responsibilities. Analyzing the results of the system characteristics, the contributing and hindering concepts, as well as the degree and reliability of their influence, are identified. We use this data to suggest solutions that are subsequently tested through structural equation modeling via the impulse-function method (Table 5).

Following our estimates, it would be appropriate, in accordance with the findings, to offer estimates of the linguistic sets in addition to quantitative data (Table 6).

A significant degree of consonance of the system's impact on the concept is achieved by Financial/Credit institution (0.75), Consumer (0.73), Provider (0.69), and Employee (0.63). The significant degree of dissonance in the system's influence on the concepts is caused by State authorities/Local self-government bodies (0.94), State institution/ Government agency (0.82), Business support funds (0.79), National Research Foundation of Ukraine (0.74). A significant degree of consonance of the concept's influence on the system is defined in such indicators as Employee (1.00), Scientific institution (0.84), Educational institution (0.78), Partner (0.72), Shareholder (0.70), Business Park/Center/Incubator, Science/Technology transfer center/Consulting center (0.70). A significant degree of dissonance of the concept's impact on the system is found in such categories as Consumer (0.75), Media (0.66), Financial/Credit institution (0.59), Grant foundation (0.54), Founder/Manager (0.58), Investor/Business angel (0.50).

4.3. Discussion

The results of our study prove the work of Kramarz et al. (2021) and Li-Ying et al. (2022) in recommendation that were made aimed at synchronizing the knowledge, business and innovation ecosystem which opens up opportunities for the transfer of science, learning and development in integrated systems of innovation, knowledge and entrepreneurship. The study by Christos et al. (2022) also identified the availability of financing opportunities, communication with stakeholders, business training, start-up experience, accelerator and coaching services as the main factors influencing the successful development of start-ups. Our study allowed us to expand the criteria for the formation of a model of innovation ecosystems by adding subsystem categories, functional features and positions.

Table 5. Evaluation of the system characteristics of the cognitive model of the influence of stakeholders in the innovative ecosystem by categories of subsystems, functional features and positions

Concept	*Symbol*	*Consonance of the influence of the system on the concept*	*Dissonance of the influence of the system on the concept*	*Consonance of the influence of the concept on the system*	*Dissonance of the influence of the concept on the system*
Educational institution	I_{IE}	0.41	0.59	0.78	0.22
Scientific institution	I_{IS}	0.44	0.56	0.84	0.16
Business entity	I_{IB}	0.42	0.58	0.68	0.32
Employee	I_{IESB}	0.63	0.37	1.00	0.00
Founder/Manager	F_{IES}	0.44	0.56	0.42	0.58
Shareholder	F_{IB1}	0.41	0.59	0.70	0.30
Consumer	F_{IB2}	0.73	0.27	0.25	0.75
Investor/Business angel	F_{IB3}	0.36	0.64	0.50	0.50
Financial/Credit institution	F_{IESB}	0.75	0.25	0.41	0.59
Student	F_{IE}	0.50	0.50	0.62	0.38
Business association (Corporation/Consortium/Concern)	P_{IB}	0.41	0.59	0.54	0.46
Science/Innovation park/Technology park/Technopolis	P_{IESB}	0.38	0.62	0.62	0.38
Coworking/Educational and creative hubs	P_{IES}	0.29	0.71	0.37	0.63
Business Park/Center/Incubator. Science/Technology transfer center/Consulting center.	P_{ISB}	0.33	0.67	0.70	0.30
State authorities/Local self-government bodies	I_{EESB}	0.06	0.94	0.56	0.44
Provider	I_{EB}	0.69	0.31	0.55	0.28
Partner	I_{EESB1}	0.46	0.54	0.72	0.45
Government institution/State institution	I_{EESB}	0.18	0.82	0.66	0.34
National Research Fund of Ukraine	F_{ES}	0.26	0.74	0.67	0.33
Business support funds	F_{EB}	0.21	0.79	0.56	0.44
Grant foundation	F_{EES}	0.31	0.69	0.46	0.54
Charitable foundation	F_{EESB}	0.22	0.78	0.57	0.43
Media	P_{EESB1}	0.58	0.42	0.34	0.66
Public association/Organization/ Non-governmental organization	P_{EESB1}	0.38	0.62	0.54	0.46
International/Scientific and Technical alliance	P_{ESB}	0.43	0.57	0.61	0.39
Cluster/Transnational corporation/Financial/industrial group/International group of companies (P_{EB})	P_{EB}	0.45	0.55	0.60	0.40

Source: Authors' elaboration.

Table 6. Scales and criteria of system characteristics of the cognitive model of influence of stakeholders in the innovation ecosystem by categories of subsystems, functional features and positions

Notation of the integral indicator	*Criteria of the system characteristics of the cognitive model for identifying cause-and-effect relationships of the influence of stakeholders of the innovation ecosystem*		
	Low	*Medium*	*High*
Consonance of the influence of the system on the concept	[0.06; 0.29)	[0.29; 0.52)	[0.52; 0.75]
Dissonance of the influence of the system on the concept	[0.25; 0.48)	[0.48; 0.71)	[0.71; 0.94]
Consonance of the influence of the concept on the system	[0.25; 0.50)	[0.50; 0.75)	[0.75; 0.1]
Dissonance of the influence of the concept on the system	[0; 0.25)	[0.25; 0.5)	[0.5; 0.75]

Source: Authors' elaboration.

5. CONCLUSION

According to the modeling results, stakeholders as elements of the innovation subsystem, such as employees, educational institutions, and research institutions, have the greatest impact on development. Attracting and retaining the necessary employees, providing them with opportunities for development, and improving their competencies allows us to ensure the highest level of productivity and service quality.

Also, educational and scientific institutions, which are key elements of the innovation network, are identified as a determining factor in the effectiveness of the innovation network. Innovation is a defining aspect of their activities and provides dynamic incentives for an effective mechanism of interaction. Supporting some of these structures will help unlock educational, research, and innovation potential, ensure a high degree of social responsibility in the community, and help ensure innovative development.

Among the concepts of direct influence on the innovation network, financial support from shareholders is also needed. An open dialog, understanding of business strategy and corporate governance allow for effective interaction with shareholders. Today, an essential aspect of building an innovation network is the organization of business parks, business centers, business incubators, science and technology centers, technology transfer centers, consulting centers, etc. The activities of these potential stakeholders involve interaction on a parity and regular basis, based on the principles of social partnership.

The study has determined that the dissonance of the system's impact on the structure is the efforts of the authorities and local governments to encourage creativity and intensify the introduction of innovations. The authors also prove the negative impact on state financial support funds, which complicates the prospects for the development and establishment of innovative activities. It should be noted that the categories of dissonance mainly define the external environment stakeholders, which indicates the need to identify tools for communicating with these stakeholders, creating opportunities for development and ensuring a positive contribution to joint activities.

The vast majority of dissonances in the impact of the concept on the innovation network are concentrated in the financial subsystem. Lack of awareness of additional funding opportunities, such as grants, investors, and business angels, limits potential resources for innovation. On the upside, the prospects and opportunities for innovative technologies attract potential financial institutions that are interested in cooperating with high-quality long-term projects.

Strengthening the connection between the industrial transition and other societal events can be realized through the development of innovative technologies, industrial processes and new business models by strengthening human-centeredness and sustainability. Managing the networked society requires new tools, partnerships and goals that affect industry, the knowledge society and the economy.

According to the structure and strength of the relationships, it is advisable to identify trends and problems in the development of interaction between education, science and business stakeholders and build a model using two types of qualitative analysis and a quantitative network analysis tool, which will help to identify the potential, trajectory and directions of interaction between education, science and business stakeholders.

The results of the study show that the structure of stakeholders in the innovation system is based on different criteria. The obtained results determine the influence of stakeholders within the innovation system. Potential users of the research results are participants in innovation relations, which will allow them to improve the quality and reliability of interaction and identify points of growth and stabilization. Practical implications include recommendations for the development of innovation programs that implement interaction between universities, institutions and industry. The implications and limitations of this study include the difficulty of determining the interaction between individual stakeholders due to the multilateral opportunities for their contact.

The diagnostics of stakeholders of education, science and business in the implementation of innovation activities allows to form a list of barriers to effective communication and to study the level of values and expectations of representatives of different groups of stakeholders. The perspective of further research is to modeling the tools for strategic goal setting and planning of involvement of stakeholders of education, science and business in innovation activities.

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