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THE SCIENTIFIC-POPULAR ELECTRONIC  
JOURNAL "INNOVATION SCIENCE AND  
TECHNOLOGY" HAS BEEN REGISTERED  
UNDER THE NUMBER **C-5669633** BY THE  
AGENCY FOR INFORMATION AND MASS  
COMMUNICATIONS (AOKA) OF THE  
REPUBLIC OF UZBEKISTAN, EFFECTIVE  
FROM OCTOBER 9, 2024.

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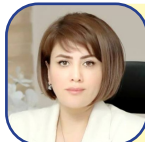
**Website:** <https://ist-journal.uz>

**Email:** [munis.iriskulova@gmail.com](mailto:munis.iriskulova@gmail.com)

Electronic publication, Issue 1. 119 pages. Approved for  
publication on January 23, 2025.

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# SPIRAL MODELS OF INNOVATIVE DEVELOPMENT: TRIPLE, QUADRUPLE AND FIVE HELIX MODELS

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**Abstract:** The article analyzes the progress of the innovative Triple Helix model, the reasons and conditions for its change. The initial model considered the interaction of the state, business structures and the scientific (including university) community. The article demonstrates how the interaction of elements becomes more complex with the appearance of a fourth element, called the "public" (mass media, culture, creative industry, etc.). The role of this element in the innovation model of the Quad Spiral is investigated. The significance of the work is to clarify the characteristics and conditions of complication of innovative interaction. The innovation model of the Five Helix illustrates what qualitative changes occur in the relationships of participants in the innovation process. It accumulates environmental and social aspects of development.

**Key words:** Innovation models, innovation model of the triple helix, the fourth helix of innovation, the fifth helix of innovation, open innovation.

## INTRODUCTION

Innovation processes are multi-faceted and dynamic mechanisms that can vary depending on the context, goals, and resources. Linear modeling of innovation processes assumed a strict sequence of implementation of innovative research and development, in which each next stage starts after the previous one is completed.

However, a systematic approach to technological development, broad digital transformation and the dissemination of ESG values (environmental, social and managerial aspects) lead to the fact that innovation becomes a complex process based on multi-stakeholder interaction. In such conditions, management innovations take a leading position in the search for new effective models of interaction between all participants in the innovation process. [2]

## REVIEW OF LITERATURE ON THE SUBJECT

The spiral models of innovative development, including the triple, quadruple, and five helix models, represent significant frameworks in understanding the dynamics of innovation ecosystems. These models emphasize the interactions between different societal actors, such as academia, industry, government, and additional stakeholders like civil society and the environment.

Etzkowitz and Leydesdorff introduced the triple helix model, which highlights the interplay between universities, industries, and governments as the foundational structure of innovation systems. Their work underscores the importance of these interactions in fostering knowledge transfer, economic development, and social transformation. The triple helix model is widely recognized for its applicability in both developed and developing economies, adapting to the specific needs of regional innovation systems.

Building upon the triple helix, Carayannis and Campbell proposed the quadruple and five helix models, which expand the scope to include the "media-based and culture-based public" and the "natural environment" as integral components of innovation systems. The quadruple helix emphasizes the role of civil society and media in shaping innovation processes, while the five helix incorporates sustainability and ecological considerations. These models reflect the growing complexity and interdependence of actors in modern innovation ecosystems.

Further studies, such as those by Ranga and Etzkowitz, have explored the implementation of the triple helix in different national and regional contexts, demonstrating how local innovation strategies can benefit from

adapting the model. Their findings highlight the need for collaborative governance and policy alignment to maximize the benefits of these interactions.

Godin and Gingras critically examined the historical development of innovation models, stressing the transition from linear models to more dynamic, multi-actor frameworks. Their research provides valuable insights into how these models have evolved to address contemporary challenges.

In addition, Leydesdorff and Deakin analyzed urban and regional innovation systems using the quadruple helix, emphasizing the need for sustainable urban development and the importance of engaging a broad range of stakeholders in the innovation process. Their findings underline the adaptability of these models to various scales of governance and societal challenges.

Scholars such as Carayannis and Grigoroudis have further extended the five helix model by proposing methods for assessing innovation performance, focusing on the interaction between economic, social, and environmental dimensions. These advancements demonstrate the potential of the five helix model to address global sustainability challenges while driving innovation.

The spiral models provide a comprehensive framework for analyzing innovation ecosystems, but challenges remain in operationalizing these models in diverse contexts. Issues such as governance complexity, cultural differences, and resource limitations need to be addressed to fully realize the potential of these approaches.

## RESEARCH METHODOLOGY

The theoretical and methodological foundations of the research are system-structural and system-functional approaches to studying the relationships of socio-economic systems and their main components. The main research tasks are solved using various methods of scientific analysis: comparative, historical, mathematical and statistical analysis.

## ANALYSIS AND RESULTS

The priority of the closed innovation model was the development of innovators within the company. External resources were attracted only through integration into the organizational structure, usually in a vertical hierarchy. Interaction and collaboration were not considered; instead, the emphasis was placed on subordinating the interests of innovators to the interests of the company. Management sought to create an atmosphere of creativity and create an innovative culture within the organization. The search for innovative ideas could take place from the outside, but it was most often a passive, one-sided process with low efficiency, since when one participant “closes”, accepting the role of a “recipient” of knowledge and information, this leads to restraint on the part of other participants in the scientific and technological sphere.

An open innovation model implies new flows of knowledge, ideas, and technologies that permeate the organization in various ways. The main focus is on finding and developing various forms of cooperation with participants in the global innovation process: research organizations, universities, competitors, state development institutions and non-profit industry associations, as well as suppliers and consumers. A key aspect of the implementation of the open innovation model is the development of a network of contacts with all those interested in cooperation in science, technology, marketing, management and other areas. Such a broad reach is necessary in order to let in the “spirit of invention” and be ready for changes in any area of the company’s activities.

Innovative development of the economies of various countries implies a scenario of development according to various models, among which the Euro-Atlantic, East Asian, and Alternative models are distinguished. However, the constant development and improvement of innovation processes has led to the emergence of completely new models of the spiral form of development.

Innovative Triple Helix model (Triple helix model of innovation) involves interaction between universities engaged in basic scientific research, businesses that create value, and public administration that performs the functions of coordination, regulation, and control [3].

The triple helix model describes the interaction of the three main institutions of society-science, government, and business-at various stages of creating innovative products. This dynamic model of interaction between all participants in innovation activity arises in the process of evolution of the economy and society. If in the industrial period of human history, the interaction of the three institutions was linear, then in the modern era it can be likened to the interconnected helical structure of DNA. The triple helix model allows science, government, and business to adopt and retain each other’s key characteristics. Universities are not only engaged in teaching and research, but also contribute to economic development by creating new businesses in university incubators, companies that partially provide educational services, and the state acts as a social entrepreneur and venture investor in addition to its traditional legislative and regulatory role.

In this model, the university takes a leading role, becoming an entrepreneurial or industrial university that applies knowledge in practice and invests the results obtained in new areas of education. A classic example of triple helix innovation development is the creation of Silicon Valley in the United States. Initially, the interaction was double and paired: “universities and enterprises” and “states and universities”. The main efforts of universities were focused on the development of basic and applied research, the results of which were applied in the production of industrial enterprises. The basis for success was the development of a business support policy, which was the result of many years of active work of government agencies. In the course of time, the double relationships were transformed into a triple helix model (Fig. 1).

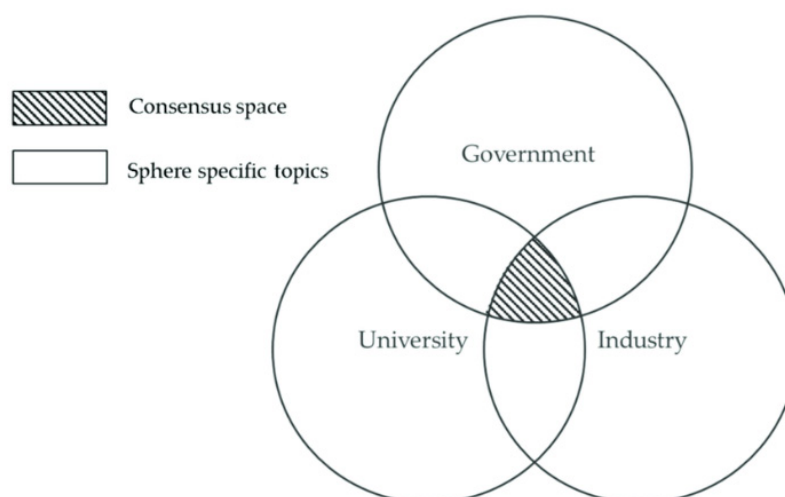


Figure 1. The Triple Helix of Innovation [4]

Interaction between universities and the government primarily depends on the financial independence of universities from the state. If they are funded from the state budget, the focus of their research is often determined by the Government. In addition, cooperation can relate to the implementation of state policies in the field of higher education, where the government, after public discussions, sets priority areas of training and educational standards.

The degree of regulation of the state's economic system also affects the government's role in business development. With a high level of regulation, the government actively directs the activities of companies. Otherwise, its efforts are focused on creating infrastructure and a favorable innovation and entrepreneurial climate, as well as protecting the interests of domestic producers in the global market.

The triple helix can be viewed as an interaction between institutional areas such as universities, business, and government, and as a series of spaces: the knowledge space, the consent space, and the innovation space (Fig. 2).

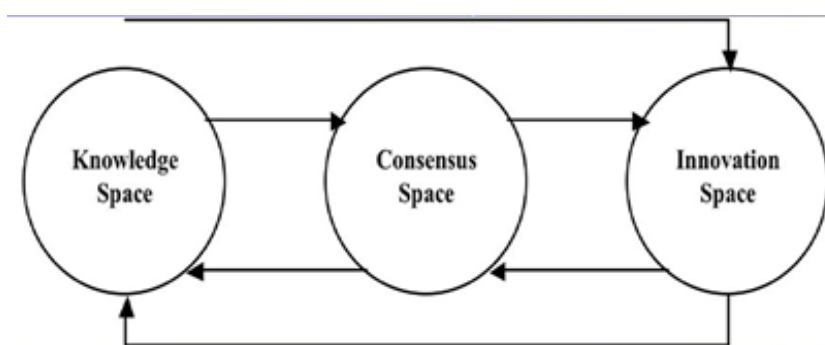


Figure 2 Triple helix spaces [5]

The triple helix model is not only about facilitating cooperation between the three main institutional players, it is also a model of space. It's about innovation, consent, and the knowledge space. The knowledge space is the existing resources of universities and companies. However, knowledge itself is only an existing ability that cannot be developed without other necessary elements. The knowledge space includes knowledge generation in universities, research institutes, and corporate research departments.

The key point is the consensus space, which brings together representatives from different institutional spheres to analyze the competitive advantages and disadvantages of the region in order to develop ideas and strategies for the development of the region. The consensus space allows you to bring together people from different fields of knowledge who can discuss how to develop strengths and solve existing problems in the region.

The innovation space is the creation of a new organizational format that is designed to correct shortcomings in the development of the region. This may include, for example, creating a new type of organization. The innovation space is necessary for the other 2 spaces. In this case, the problem of organizing a new project is the result of the activities of all three institutional areas, so resources must be obtained from all sources. All three sources are responsible for developing further actions. When venture capital is organized, it receives resources not only from the state, but also from universities that can provide them, and university graduates can help with business advice. Thus, the organization became a hybrid one. The key to success was collaboration between all participants in the model.

Further research on the Triple Helix model and its application to the emerging knowledge economy led to the emergence of the Quadruple Helix model (Quadruple Helix model). A systematic approach to the processes of knowledge generation and management allowed Karayanis E. and Campbell D. to conclude that «in fact, there is co-competition, joint specialization and joint evolution of various methods of knowledge» (co-opetition, co-specialization, co-evolution, 3C) [6]. Heterogeneity of approaches to knowledge and their mutual integration should lead to a significant synergistic effect.

Karajanis E. and Campbell D. proposed to supplement the Triple Helix of Leidesdorf and Itzkowitz with a fourth helix – the public, which means primarily “media”, “creative industry”, “culture”, “values”, “lifestyles”, “art”, and possibly “creative class”. The culture and value orientations of society, on the one hand, and the participation of the media in shaping public consciousness, communicating knowledge, innovation, and popularizing science and technology, on the other, have a significant potential to influence the development of the knowledge economy and the transition to industry 4.0 [1].

The four-link innovation spiral connects “social ecology, third-level knowledge production, and innovation” [7]. The third type of knowledge is related to the learning process, cognitive activity, and learning of cognitive activity. It is based on the search for unusual relationships, a non-linear approach to the problem, and creativity.

The four-link spiral reflects the interaction of four subsystems:

- \* science and education (universities and research organizations);
- \* economic sector (industry, services and banking, etc.);
- \* state and political institutions that set the vector of socio-economic and innovative development;
- \* the public (representatives of the media and culture) (Fig. 3).

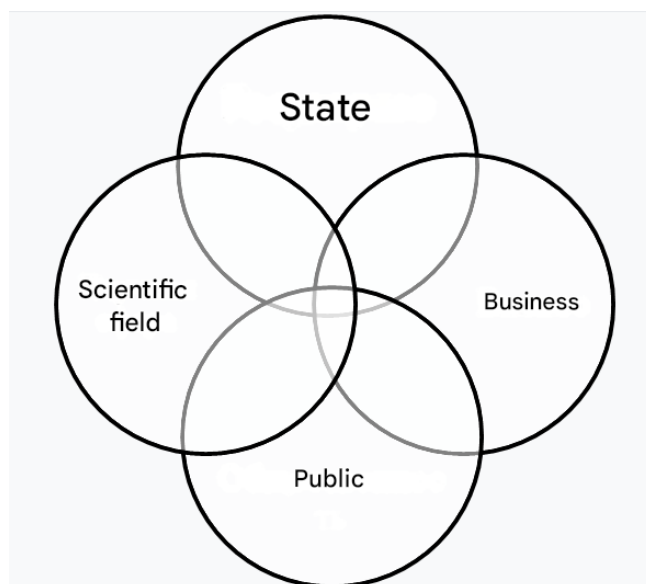


Figure 3. Four-link innovation spiral  
[compiled by the author]

This subsystem is the core of the Fourfold Innovation Spiral, since it determines the orientation of the entire system to create innovations for users, i.e. for society. This is the driving force of the innovation process, which determines its trajectory, depth and ensures efficiency.

The task of the media is to support the dissemination of knowledge. The efforts of the cultural community should be directed to the formation and maintenance of the value of knowledge, the culture of knowledge and the dissemination of knowledge.

The scientific and educational community, business, and public-political institutions influence from the top down, while society and its institutions influence from the bottom up. In addition, subsystems actively enter into relations with each other horizontally, up to interpenetration, which is implemented in innovative forms of institutions and other structures [8].

Building interaction between competitors in the field of providing resources and capital for innovative research and development can be beneficial for competing parties in terms of protecting the market from new players, the appearance of substitute products, and ensuring long-term competitiveness. That is, they can use the concept of equilibrium, according to which competing parties can develop a position that will ensure that they reach a state that will satisfy everyone. Co-competition in the knowledge economy is implemented, including in the organization of interaction aimed at joint creation of new knowledge at different levels of business development. Moreover, this new knowledge can be either the result of direct cooperation of “competitors”, or an indirect (“by-product”) product of one of the parties to co-competition, which appeared as a result of a “lucky chance” in cognition [7]. The mutual participation of the four subsystems of this model is also realized through the development of mutual specialization or co-specialization, which implies a higher efficiency of joint participation of companies in research and development. The same applies to the process of generating new knowledge, more active knowledge of new things, and expanding the scope of research in the process of cooperation.

The urgency of environmental issues and environmental protection contributed to the further development of the Triple Helix model and the addition of the fifth element – “the natural environment of society”. In the Quintuple Helix model, a qualitative transformation of relationships takes place by adding another helix. If the Triple Helix reflects the construction of the knowledge economy, then the Fourth Helix implements the transition to building a knowledge society and knowledge democracy, which continues within the framework of the fifth model. The fifth innovation spiral accumulates environmental and social development issues. On the one hand, the environmental and social agenda is a source of knowledge and innovation, and on the other hand, it is an area that researchers and developers of innovations are focused on changing. “The Five Helix supports the formation of a win-win situation between ecology, knowledge and innovation, creating synergy between the economy, society and democracy” [9]. In this model, knowledge is transferred from spiral to spiral, i.e. the knowledge created by one spiral becomes a source for new knowledge generated by the next spiral of the Five-dimensional Model (Table 1).

Table 1. Comparative analysis of innovative models of triple, quadruple and five helices [1]

|                                                   | <b>Triple spiral</b> (Triple helix model)                                  | <b>The Quadruple Helix</b> (Quadruple Helix model)                                                                      | <b>Pyaternaya Street spiral</b> (Quintuple Helix model)                                                                                                                                                                                        |
|---------------------------------------------------|----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Authors</b>                                    | Itzkowitz and Leidesdorf                                                   | Karayannis and Campbell                                                                                                 | Karayannis and Campbell                                                                                                                                                                                                                        |
| <b>Model elements (spirals)</b>                   | State<br>Educational and scientific environment (Universities)<br>Business | State<br>Educational and scientific environment (Universities)<br>Business<br>Public (mass media, cultural communities) | State<br>Educational and scientific environment (Universities)<br>Business<br>The public (mass media, cultural communities)<br>Natural environment of society (Ecology, environmental protection).                                             |
| <b>Industrial development stage (revolutions)</b> | Industry 3.0 (informatization, automation of production processes)         | Industry 4.0 (digitalization)                                                                                           | Industry 5.0 (further technologization and digitalization has a humanistic focus: improving the quality of life, developing social responsibility, ensuring sustainability, preserving and restoring the potential of the natural environment) |

|                                                 |                                                     |                                                              |                                                                                                                                                            |
|-------------------------------------------------|-----------------------------------------------------|--------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Stage of economic and social development</b> | Knowledge Economy                                   | Knowledge Society and the emergence of a knowledge democracy | Development of knowledge democracy and socio-ecological transition to sustainable development                                                              |
| <b>Foundation of the innovation model</b>       | Linear innovation model, nonlinear innovation model | Innovative eco-system                                        | Linear innovation model, nonlinear innovation model, innovative eco-system (a variety of models, approaches, concepts as the basis of knowledge democracy) |
| <b>Trends</b>                                   | Technological innovation                            | Management innovations                                       | Eco-innovation and social entrepreneurship                                                                                                                 |

## CONCLUSION AND SUGGESTIONS

The study of the relationship between the three innovation models—triple, quadruple, and five helices—offers a comprehensive framework for understanding and modeling the future trajectory of innovative development in economies. Each successive model integrates a new element, such as the public or environmental dimensions, fundamentally transforming the dynamics between existing components. This progression signifies not just a quantitative expansion of elements, but a profound qualitative shift in how innovation ecosystems operate and interact.

The evolution of spiral innovation models is driven by multiple factors. On the one hand, it reflects an increasing academic and practical interest in exploring multi-actor collaboration as a cornerstone of innovation. On the other hand, it highlights the adaptive responses of innovation systems to evolving economic, social, scientific, and technological landscapes. These models capture the complexities of modern innovation processes, including the growing importance of sustainability, societal engagement, and open innovation.

Moreover, the interplay among these helices emphasizes the necessity for cross-sectoral synergy, creative policymaking, and strategic alignment of diverse stakeholders. By understanding these relationships, policymakers, researchers, and industry leaders can develop more robust strategies to foster inclusive and sustainable innovation, ensuring that economic growth aligns with societal and environmental goals.

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**Proofreader:** Zokir ALIBEKOV

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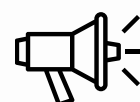
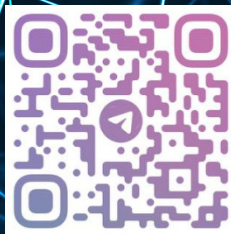
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