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## From a Triple to a Penta Helix: The Evolution of Innovative Economy Development Methodology

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**Abstract.** The presented paper deals with an approach to the evolution of methodology of economy innovative development from the standpoint of analyzing the interaction of its actors – from a Triple to a Penta Helix. The article proposes the provisions for such a methodology based on expanding the range of actors of innovative development as public interests shift from the emergence of a free enterprise economy to a socially oriented knowledge economy and further to a balanced and environmentally friendly production and consumption. A special role in the presented approach is given to the analysis of the place of universities in the fivefold spiral of innovative transformation of economy – as a creator of sustainable development values. The authors proved that the Penta Helix is the result of the evolution of the Quadruple Helix in the conditions of increasing the values of sustainable development. In turn, the core of the Quadruple Helix – the Triple Helix – acts as the core in the Penta Helix. The article highlights three varieties of the Triple Helix model that is dominant today in industrialized countries, shows their connection with the peculiarities of the innovative development of the Russian economy. On this basis, it was concluded that the progress in building the Penta Helix of innovative development in Russia depends on the emergence of new actors – the subjects of the green economy and civil society, and the full expression of their economic interests.

**Keywords:** innovation economy, actors, Triple Helix, Quadruple Helix, Penta Helix.

Research area: economics.

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## От тройной к пятеричной спирали: эволюция методологии развития инновационной экономики

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**Аннотация.** В представленной статье рассматривается подход к эволюции методологии развития инновационной экономики с позиций анализа взаимодействия ее акторов – от тройной к пятеричной спирали. В статье предлагаются положения методологии, основанной на расширении круга акторов инновационного развития по мере смещения общественного интереса от становления экономики свободного предпринимательства к социально ориентированной экономике знаний и далее – к сбалансированному и экологически безопасному производству и потреблению. Особая роль в представленном подходе отводится анализу места университетов в пятеричной инновационной трансформации экономики – как создателей ценностей устойчивого развития. Авторы доказали, что пятеричная спираль является результатом эволюции четверной спирали инноваций в условиях повышения роли ценностей устойчивого развития. В свою очередь, ядро четверной спирали – тройная спираль – действует и как ядро пятеричной спирали. В статье выделены три разновидности модели тройной спирали, доминирующей сегодня в промышленно развитых странах, показана их связь с особенностями инновационного развития российской экономики. На этом основании сделан вывод, что прогресс в формировании пятеричной спирали инновационного развития в России зависит от появления новых акторов – субъектов зеленой экономики и гражданского общества, полноты выражения их экономических интересов.

**Ключевые слова:** инновационная экономика, акторы, тройная спираль, четверная спираль, пятеричная спираль.

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### Introduction

Innovative development that accompanies the transition from an industrial economy to a knowledge economy, and further to a sustainable development economy, is non-linear and involves new stakeholders in the innovation process, making it more specialized, adapted to the needs of various actors (“innovation funnel”). In the theoretical analysis of the innovative development of modern economy and society, the helix concept is firmly rooted, the turns of which mean reaching a new level of productivity and solving the problems facing society.

Since the 1990s in the widespread model of the Triple Helix of innovative development there has been the links between three groups of actors – the state, universities and business firms, which common interests have created a solid foundation for national competitiveness. At the same time, over the past two decades the key trends of economy development are digitalization and networking, the transition to sustainable development, the greening of production and consumption, creating a special environment for innovative development, forming new coils of the helix. In this regard, the Russian

economy should form the basis for the transition to the Quadruple and Penta Helix of innovative development in order to increase national competitiveness.

Among the popular concepts of innovative development of the last two decades, the most famous are the concepts of the so-called “helix”, which explain the growth of innovative economy through the formation of effective links between science, industry and the government for the development of innovation entrepreneurship in a knowledge-based economy (Afonso et al., 2012; Cai et al., 2021; Capetillo, 2021).

### **Statement of the problem**

The turn of the spiral from inventions made at universities and scientific organizations to mass production is described in the concept of “Triple Helix” in 1995 (Etzkowitz et al., 2010). By this time, it became completely clear that the traditional scheme of invention and rationalization – factory design bureaus, Japanese corporate “quality circles” (Ishikawa, 1990), as well as state research institutes, – will not provide the necessary technological breakthroughs in the emerging at that period innovative economy.

Since then, the Triple Helix model of innovative development has become a popular concept in innovative research. It received its institutional support after the adoption in 2000 of the so-called “Lisbon Strategy” as a tool for the member countries of the European Union in the formation of a “knowledge economy” that can compete with the United States (Rodrigues, 2003). The Lisbon Strategy is based on the ideas of supporting innovation in every possible way, the acquisition by knowledge its own right and the promotion of cultural and environmental values as the “pillars” of the economy of the future. The Triple Helix here plays the role of an integrator of interests for different subjects of the innovation process in a broad sense, and form of its organization in a narrower sense. E. Cresson derives such properties of the Triple Helix from the Schumpeterian theory of innovative entrepreneurship and its contribution to the processes of economic development (Cresson, 1997).

In later works, the development of innovation activity in the Triple Helix model is presented as an evolutionary, interactive, multilateral, institutional and self-developing process of interaction between universities, the state and stakeholders – business firms, as well as a holistic approach to innovation based on a network of various organizations and technologies (Kimatu, 2016; Unger et al., 2017).

The network nature of modern innovation system, with its characteristic non-centricity and a large number of interactive horizontal relations, is consistent with the Triple Helix, in which its participants themselves form the necessary competencies in the course of creating innovations; thus, the knowledge economy is self-reproducing. This shows the non-linear activity of the innovation process, when the accumulation of knowledge in universities meets the demand from business, which receives state support; such “coils” of interactions “science-business”, “business-state”, “state-science” form a Triple Helix.

### **Methods**

In models of innovative development spirals (Triple, Quadruple, Penta), universities play the main role as developers and technology hubs, concentrators of scientific and educational relations, constantly monitoring business requests for modernization. The role of the university as a Think Tank has a number of implementation forms in the Triple Helix model – the entrepreneurial university and the academic revolution.

The concept of an entrepreneurial university, according to Y. Cai, M. Amaral, means its “improved relevance” for technology transfer to business and innovative development of the territories where it is located (Cai, Amaral, 2021). According to these authors, today many universities of the world have actually turned from educational organizations into “temples of entrepreneurial science”, forming five new norms of innovative development: capitalization of knowledge, independence from the state, mutual dependence on business, hybridization of educational and scientific activities, reflexivity in relation to demand for innovation. The adoption of these

norms by universities means gradual interpenetration of the educational and scientific interests of universities and business, the convergence of standards for training specialists, and the concentration of state innovation incentives in business environment, but not in universities.

Academic revolutions do not deny, but complement the concept of an entrepreneurial university, with the difference that they mainly affected the relationship between universities and the state.

The first academic revolution is the Humboldt reform of education in Prussia in the 19th century, when the state began to finance universities and schools directly, and the reproduction of knowledge in its modern form began (Benner, 2003).

The second academic revolution in the middle of the 20th century was associated with a massive influx of students to universities, the popularization of science and the formation of a network of informal relations between university professors around the world, which greatly accelerated various fundamental and applied research (Altbach et al., 2010).

The third academic revolution in the 1990s was associated with the formalization of university-business ties in the form of small innovative firms and industry laboratories, innovative outsourcing. Later, the state joined these ties in the form of technological platforms, first created in the European Union in the early 2000s (in Russia – after 10 years). At the same time, both the second and third academic revolutions took place in the Triple Helix model (Dotsenko et al., 2018). In modern form, the links between business, universities and the state that form the Triple Helix of innovative development include the following:

1. Research relations within the framework of grants or contracts with firms.
2. Consultations on the introduction of new technologies, post-project support of contracts with firms.
3. Licensing relations– the transfer of rights to objects of intellectual property created by universities to business firms, and the sharing of these rights with the state.

4. Financial relations– providing investments for the creation of laboratories, stands, pre-competitive research.

5. In-company training in new technologies with the participation of university professors under licenses transferred to business firms.

6. Convergent research – joint research of several universities within the framework of convergent technologies (most often in the field of NBIC convergence) commissioned by large companies in the fields of information-cognitive, nano-biochemical, bio-information technologies.

Building a model of a Triple Helix of innovative development around these relations among universities, the state and business firms implies the allocation of three components of this model:

A) subjects – universities, government bodies (as a rule, regulating science and higher education, line ministries and regional administrations) and stakeholders;

B) economic relations associated with the pricing of innovations, with the attraction of loans and investments, with the creation and transfer of technologies;

C) competencies created within the framework of network interactions in the Triple Helix model and allowing firms to successfully implement innovations received from universities and form a request for new ones.

The ratio of these components and the level of development of relations between the subjects of the Triple Helix make it possible to distinguish three varieties of this model (Carayannis et al., 2009):

- a static Triple Helix of the first type (Triple Helix I), in which the state determines the directions of research supported by grants, stimulating the development of innovative business activities in certain areas;
- a liberal model of the Triple Helix of the second type (Triple Helix II Laissez-Faire), which institutionally separates the state and interacting universities and business in terms of goals and objectives, funding and regulation tools;
- a balanced model of a Triple Helix of the third type (Triple Helix III), in which

the interests, capabilities and resources of all three groups of its subjects are mutually intertwined and overlap, and the request for innovation is consistently dictated by both business and the state, within the framework of innovative development strategies and targeted programs.

It can be mentioned that in the Russian economy since the 2000s the first type of Triple Helix has been implemented, however, there is a request for a third type, which is confirmed by the data displayed in Fig. 1.

As follows from the data presented in Fig. 1 in the first half of the 2010s Russian state-owned organizations financed half of the spending on science and research, while since 2015 its share has been reduced to one third. At the same time, the share of total spending on research and development in the Russian economy does not increase and amounts to about 1 % of GDP, which is 2–3 times lower than in the EU countries, and 4 times lower than in China. This indicates an increase in the share of business in R&D financing, which indicates the successful formation of a Triple Helix of innovative development, which is confirmed by

the growth in demand for the latest technologies from the economy (Fig. 2).

The data presented in Fig. 2 indicate an increase in demand for technologies in the Russian economy, which is confirmed by a threefold increase in the number of applied nanotechnologies over the period 2010–2020. At the same time, the Triple Helix of innovative cooperation between research institutes and universities, the state and business, using the example of nanotechnologies, has not increased its effectiveness since 2014, when the growth of their creation in Russia gave way to a decline.

The problem of the effectiveness of the Triple Helix model in the Russian economy has its own limitations in the effectiveness of stimulating the innovation process at the societal level. First, the Triple Helix requires an organized process of interaction between universities and business, in particular, a large number of contracts between them. Secondly, the rationality of the participants in the innovation process makes them restrain the spread of innovations in order to obtain the maximum benefit, using the terms of contracts, patent protection, etc. At

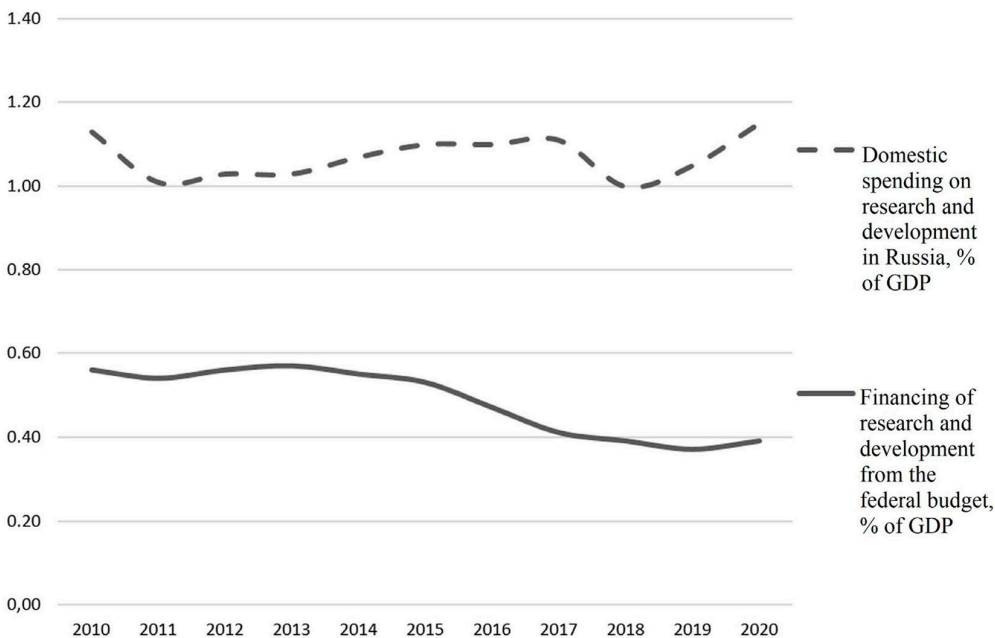


Fig. 1. Dynamics of total domestic spending and budgetary financing of research and development in Russia.

Source: (ROSSTAT, 2020)

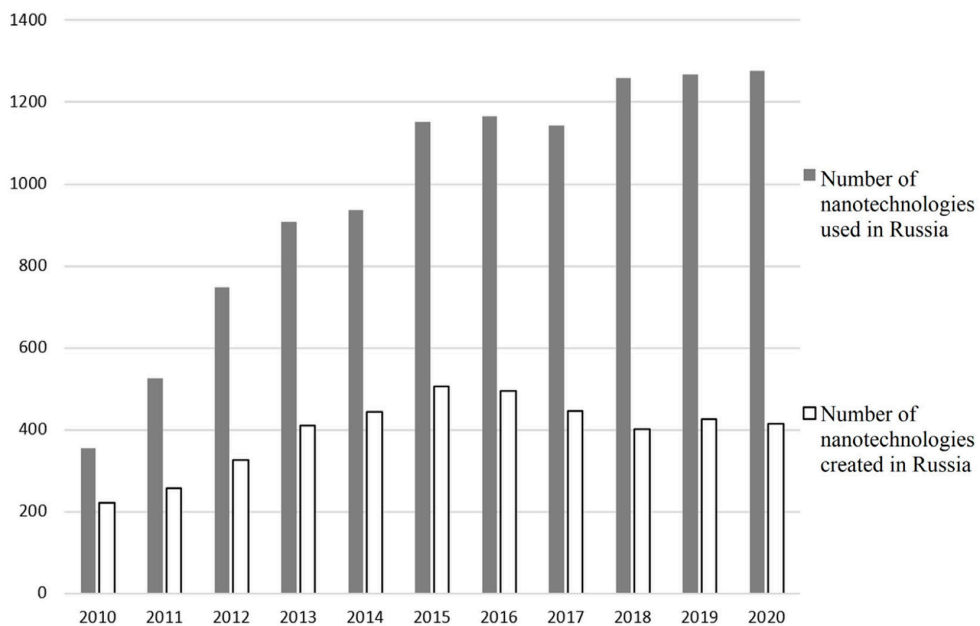


Fig. 2. Dynamics of number of nanotechnologies used and created in Russia.

Source: (ROSSTAT, 2020)

the same time, theoretically, in the horizontal plan, the Triple Helix expands due to the inclusion of other actors in it – law firms, patent attorneys, individual researchers, while vertical development (transition to the next coil) may slow down (Leydesdorff et al., 1998).

Taking into account these limitations make it possible to outline further ways of developing the Triple Helix model to accelerate the innovation process when new demands from society and technological breakthroughs appear. Summarizing the opinions of researchers, we can distinguish the following predicted paths for the development of the Triple Helix.

The first way is to increase the capitalization of universities, by turning most of them into entrepreneurial universities, in which all six types of links between the elements of the Triple Helix described above are formed and implemented.

The second way for universities is to become engines of innovative transformation of entire industries and to replace corporate scientific organizations and laboratories with them. The high level of competition between modern universities, as well as their leadership in con-

ducting basic research, allows firms to access truly breakthrough and “end-to-end” (affecting productivity throughout the industry) technologies.

The third way is a new conceptualization of the spiral development of the innovation process, which can be proposed by the state in response to the challenges of national competitiveness. This means that, in addition to firms and universities, other actors that form a demand for the transformation of traditional state functions of promoting innovation will become among the priority participants in innovation activity.

In this regard, in the last decade, the prospect of transforming the involvement of the general public in innovation activities, switching the attention of nation states from economic growth to the greening of industry and sustainable development has been actively discussed (Bina, 2013; Dotsenko et al., 2018; Khasanova et al., 2020). In this regard, new definitions of future concepts of innovative development arise – Quadruple and Penta Helix.

A number of authors observe the evolutionary process of transforming the Triple He-

lix of technological development into a Quadruple, in which conditions are created for the involvement of civil society in the innovation process (de Lima Figueiredo et al., 2022). The very concept of the Triple Helix, according to these authors, is perfect when it comes to innovations that are in demand in the field of material production and market services. However, in the field of social services, taking into account the needs of civil society in organizing the innovation process is not so obvious. Therefore, as an addition to the groups of actors traditional for the Triple Helix (universities-firms-government), supporters of the concept of Quadruple Helix add non-profit organizations involved in the development of social innovations. This broadens the range of stakeholders in technology transfer in the context of implementing the countries' intellectual specialty strategy, which is currently built on Triple Helix links in the European Union.

While the concept of the Triple Helix was developed as an intellectual response to the emerging in the 1990s knowledge economy, the Quadruple Helix model was proposed as part of the concept of "multidimensional innovation" in the 21st century (Perez, 2010). One of the first scientists to describe the transformation of the Triple Helix into a Quadruple Helix in the near future was E. G. Carayannis and D.F.J. Campbell, who identified three drivers of innovative development in 2010–2030s: individual entrepreneurship, convergent technologies, and free expression of public opinion. According to them, another turn of the spiral means "...a transition from an ecosystem of fractal innovations to a public space for innovation based on media and culture" (Carayannis et al., 2009).

In other words, the Quadruple Helix illustrates that in today's society and knowledge economy, in addition to universities, industry and the state, innovations penetrate into all spheres of society, forming a nationwide innovation ecosystem. Y. Cai and M. Amaral describe society, in relation to the Quadruple Helix, as the interaction between groups of people, institutions and knowledge (Carayannis et al., 2009). L. Leydesdorff and H. W. Park, on the contrary, argued that the perception of civil society as an additional spiral is problem-

atic because it does not have the same characteristics as universities, industry and government (Leydesdorff et al., 2014). At the same time, in line with the democratization of science as a trend foreseen at the end of the 20th century, new models for the dissemination of knowledge and the development of the innovation process are emerging, since as scientific and technological progress unfolds in society, interest in knowledge and its practical application increases. Therefore, the Quadruple Helix is seen by A. L. Volkova and M. A. Gasanov as a model of a living laboratory focused on partnership between the state, society and business (Volkova et al., 2021).

Approaches to understanding society as a subject of the Quadruple Helix should be singled out separately. Thus, A. Erkkö and D. W. Llewellyn talk about an innovative ecosystem in which people fulfill their requests for power (Erkkö et al., 2014); M. Hurenkamp, E. Tonkens, and J. W. Duyvendak consider society as a spokesman for environmental, economic, social and other interests (Hurenkamp et al., 2012). That is, it is in society that the spatial aspect of innovations is realized, which originate in universities and spread globally, since universities, business firms, and government officials are also integrated into society.

## Results

The Quadruple Helix is a continuation of the theory of knowledge economy and innovation economy, embodied in the Triple Helix model. The next round of innovative development, giving a Quadruple Helix, is generated by the knowledge that is created at universities and transferred by business or state for the use of society. Despite the fact that the issue of the sufficiency of involving society in the innovation process for long-term economic growth is debatable, one should agree with O. Afonso, S. Monteiro, M. Thompson that the growth of modern economies requires cooperation between all economic agents, including civil society (Afonso et al., 2012). Such cooperation can take the form of building competencies among the general population that allow designing user innovations, outlining improvements in relationships that form a Triple Helix. Also,

new connections within the Quadruple Helix model, in which civil society is involved, can take the form of network interactions between consumers and producers, as well as between citizens and the state (for example, in the “electronic government” system).

The interest of firms in involving civil society in the innovation process is dictated by the fact that market competition has now reached such a global and technological level that manufacturers can no longer rely on maintaining competitive advantages based on value for money. Therefore, firms’ new innovation strategies often include increasingly open business models and direct consumer involvement at various stages of the innovation process. Such “user innovative practices” in a number of countries also apply to public services, making them less costly and of better quality.

In the Quadruple Helix, what F. Gault called “user-driven innovation” is born, which was originally associated with the movement of the consumer to the center of innovation process (Gault, 2019) As a result, the number of possible innovations is multiplied many times, and with the availability of infrastructure, allows firms to adapt production with minimal time and investment (for example, within the framework of “modular” production). In general, the Quadruple Helix of innovation activity allows it to be extended to areas inaccessible to the Triple Helix – the social sphere, public administration. If universities and firms in the Triple Helix are focused on the production of high-tech goods and services based on the latest technologies and knowledge, then the Quadruple Helix is more focused on their wide distribution in society. Therefore, this model for the development of innovative activity is ideal for university start-ups and innovative micro-firms that attract investments in the form of crowd investing and venture capital.

Along with this, the Quadruple Helix can be used in the process of innovative development of industries engaged in the production of goods for public demand – health care, utilities, social services, and the digital form of public services. In turn, the refusal to accept the concept of a Quadruple Helix in the regulation of innovation activity means insufficient involve-

ment of civil society in innovation, which can cause problems such as the “fading” of innovation, when fundamental research does not reach production, a decrease in the effectiveness of investment in innovation and weakening of university innovation activity.

The expansion of the circle of actors in the Quadruple Helix model makes it possible to refer to them specific subjects of economy, which can be grouped as follows.

The first group is government organizations at the international and national levels that create strategies, ensure innovative development and digitalization related to the principles of sustainable development and the integration of different social groups.

The second group is local authorities interested in promoting digital initiatives among the general population to improve the quality of life.

The third group is public organizations that develop digital employment, healthcare, and education services.

The fourth group is a wide range of organizations in the field of education and culture, except for universities (schools, educational centers, museums, libraries, engaged in actively raising the educational and cultural level of the population).

The fifth group is employers interested in improving the innovative and digital competencies of their employees.

The sixth group is public organizations that specify their needs for innovation through surveys, open discussions and the participation of their representatives in the implementation and evaluation of digital initiatives.

Today, the global agenda of discussions on the development of society in the 21st century is closely related to environmental safety and sustainable development, so the new model of innovation activity – the Penta Helix – is aimed at maximizing the inclusion of “green” innovations in the interests of business and the state (Carayannis et al., 2012). This can be achieved by integrating eco-innovation, venture capital and green entrepreneurship focused on promoting the values of sustainable production. In turn, civil society today forms a demand for environmentally friendly consumption as an



elite type of behavior, creating the demand for eco-innovations.

The place of universities as centers of excellence in the Penta Helix is transforming from a generator of innovation to a creator of sustainable development values, which take shape in zero waste production, alternative energy, biodegradable packaging, etc. An important role in the fivefold spiral is played by innovations that are created by society itself in pursuit of the goals of a healthy lifestyle, living in ecologically clean areas, and reducing waste. In turn, states seek to stimulate the fight against climate change, which causes natural disasters, with the reduction of the ocean biosphere, with epidemics and pandemics. In addition, at the interstate level, today it is relevant to discuss the development of industry in the context of the impending de-

pletion of many mineral reserves, greenhouse gas emissions and the threat of flooding in a number of European regions (United Nations Environment Program, 2022).

Thus, the evolution of models for the development of innovation activity from a Triple to a Penta Helix can be represented as a scheme in Fig. 3.

As follows from Fig. 3, the development of innovative activity helix occurs along the path of adding new stakeholders – from innovative business to an environmentally active part of civil society and the business community. At the same time, the involvement of new groups of authors in the innovation process is due to its comprehensive nature, and in the future, it is likely to continue in the direction of the diffusion of convergent technologies in various areas of public life.

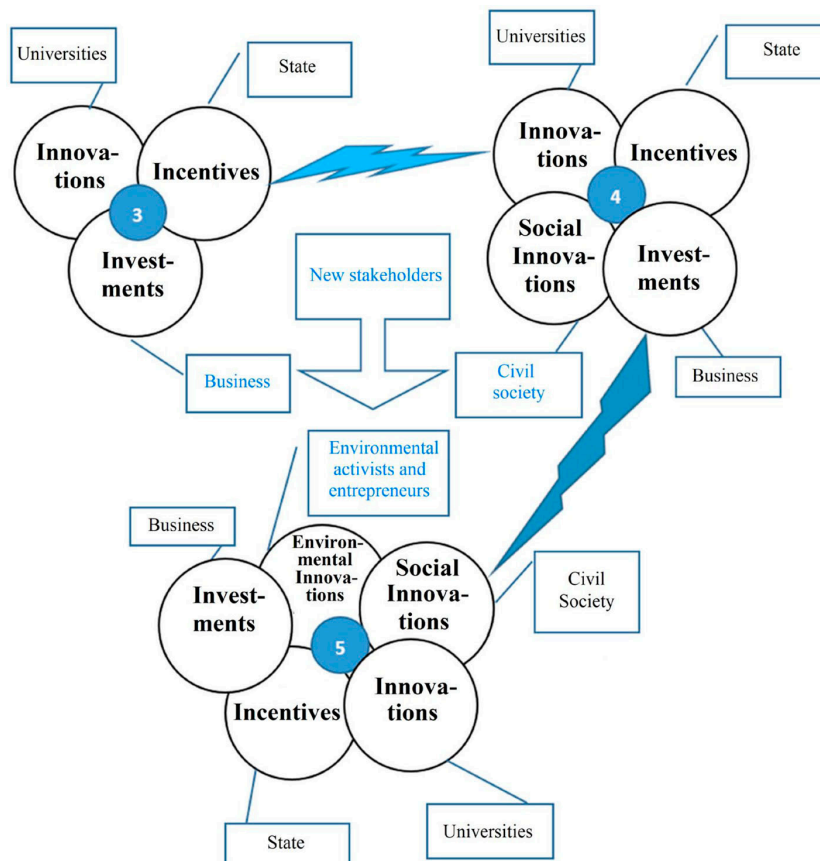


Fig. 3. Transformation of models of innovative economic development – from a Triple to a Penta Helix.

## Discussion

All mentioned above makes it possible to argue that the fivefold spiral is the next stage in the development of the Quadruple Helix under new conditions, when the values of the “green” economy and sustainable development are basic for social innovation, and public interest in them becomes universal. In turn, the core of the Quadruple Helix – the Triple Helix – as a model of innovative development retains its role.

The new element of the Penta Helix model, which expresses the environmental interests of society, the state and business, is heterogeneous and includes the following actors.

First, investors in “green” technologies – large companies engaged in alternative energy, recycling and waste processing, as well as venture funds and investment companies that finance the creation of technologies that adapt the industry to new global environmental requirements.

Secondly, the mass media, including digital publications, promoting in society the ideas of greening production and consumption, careful handling of non-renewable natural resources, environmental volunteering, etc.

Thirdly, organizations and companies that create the infrastructure of the “green” economy – parks and recreational areas, waste processing enterprises and companies using closed production cycles, developers of digital products for monitoring the environment.

## Conclusion

The spiral (helix) nature of the development of innovation activity is due to the constant formation of new relations between business, science and education, as well as the state, resulting in the emergence of new stakeholders interested in innovation. At each coil of the helix, there are new needs for innovation on the part of society and the state, which are embodied in the system of scientific and industrial cooperation between business and state. The transformation of classical universities into entrepreneurial universities, the academic revolutions of the last two centuries have created new links between business and government, in which values that extend beyond new technologies and know-how are born. These values are associated with social and environmental innovation, with crowd funding and crowd investing, with the fruits of digitalization and technological convergence.

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