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The six-helix model of technology transfer innovation ecosystem

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Abstract: Based on the analysis of the development of models of technology transfer, the concept of open innovation, innovation systems and innovation ecosystems, the approach of an effective technology transfer in the conditions of the development of innovative economy is proposed. A multi-level technology transfer ecosystem is proposed in the "Six Helix" innovation ecosystem model, which is based on the generation of new innovative enterprises based on technologies developed in research institutes/universities using: direct classical technology transfer, reverse technology transfer and outward transfer of open innovations.

Key words: innovation; open innovation; innovation ecosystem; technology transfer ecosystem; model ecosystem.

1. Introduction

In modern conditions of dynamic change, the main trend in the world economy and national economies is the presence of dominant factors characteristic of the development of innovative economy, where the main source of innovation is science and education, which ensure sustainable economic growth by implementation of the innovation.

The growth of relevance and economic feasibility has contributed to the development of innovation system (IS) that can ensure the systematic creation of innovations, taking into account national, sectorial and regional characteristics.

Technology transfer is an integral part of the innovation system, which allows to ensure the effectiveness of innovation. Academic entrepreneurship has become a key approach to technology transfer from the world's leading research organizations and universities.

However, with the growing dynamics of the environment and global challenges, there is a need to apply new approaches to the development of innovation systems and academic entrepreneurship, namely the application of the technology transfer ecosystem (TTE) approach.

2. Research of existing solutions of the problem

The transfer of university technology has become an important and independent area of research over the past few decades. Given the enormous challenges of transferring science to the market, many universities have set up technology transfer offices, science parks, incubators and university venture funds, called the Technology Transfer Ecosystem (TTE) [1].

The presence of an innovative system (IS) with clearly defined institutional and organizational elements is a key factor in the success of cooperation between research organizations, universities and industry for technology transfer activities [2].

One of the effective approaches to technology transfer is academic entrepreneurship, which has developed from teaching, research to entrepreneurship in higher education and is to create startups and spin enterprises based on scientific results achieved in research laboratories of academic research organizations and universities [3, 4].

The technology transfer system is an integral part of the innovation system (IS), the key elements of which are private and public universities, research institutes, research units, spin-offs that turn new knowledge, scientific solutions and results into market products and services. Important elements of the innovation system (IS) are innovation centers, technology parks, technology transfer centers, academic incubators, financial support institutions (funds, venture capital, business angels) and institutions of market providers of consulting, training and information services. Academic entrepreneurship has a positive impact on the economy on a micro-meso-macro scale of innovation systems (IS), as evidenced by successful examples of technology transfer within the spin of enterprises organized by scientists. [5].

Academic entrepreneurship can use organizational forms of technology transfer, namely: organizational unit or specialized department of technology transfer within research organizations (universities); organizations working outside the research organization and associated with the research organization or a specific technology transfer department of the research organization; public or private, independent intermediary serving more than only one research organization (university) [6]

The development of academic entrepreneurship within the framework of innovation systems was based on the use of various models of technology transfer.

Joseph A. Schumpeter (1934) proposed the technology transfer (TT), as the main condition for the competitive development of innovation and development of society. The main provisions of this model are as follows: 1. Inventive activity, in fact, is outside the economy, and entrepreneurs only track discoveries, create inventions and other innovations based on them, and use them for profit. 2. The development of the economy goes through technological innovation, causing the efforts of entrepreneurs, the emergence of new products and processes.3. The innovation process begins with the invention and ends with a profitable innovation [7].

Technology transfer (TT) assignment models, which were developed in the 1945s and 1950s, assume that good or quality technologies sell themselves. The researchers develop the technology and make technologies available through various forms of communications such as technical reports and professional journals; the users will “automatically show up at the researcher’s door”.

During 1980s - 1990s, TT models have started to absorb the principles of the organization development and strategic management. One of the most common were the dissemination model, knowledge utilization model and communication model. The dissemination TT models suggests the importance of technology to been disseminated to the potential users and assumes that an expert will transfer specialized knowledge to the willing user. The knowledge utilization TT models is its emphasis on interpersonal communication between the technology researchers - users, and the importance of facilitators of TT. The communication TT models perceives TT suggests technology as “an on-going process which involves a two-way interactive communication [8].

The Bar-Saki’s technology transfer (TT) model (1971) divides the transfer technology process into stages based on the use of a project management approach. The technology transfer activities carried out are been based on the importance of using technological forecasting and long-term planning related to the research project [9].

The Bar-Zaki transfer technology model has limitations, as buyers have relied heavily on government assistance programs.

The Behrman – Wallender technology transfer (TT) model (1976) is been based on the use of seven stages of international technology transfer, which may be more relevant for multinational

corporations: 1.Proposal - production and planning. 2. Making a decision about the design technology of the products to be transferred. 3. Pilot tasks for the production of designed products, construction of infrastructure. 4. Construction and start of production. 5. Adaptation of the process and product, if necessary and strengthening of production systems taking into account local conditions.6 Improve technology using local skills. 7. Providing external support to strengthen the relationship between the developer and the recipient of the technology [10].

One of the disadvantages of this model is that, during the first three stages, the development of the technology transfer project takes place with minimal involvement of the recipient.

The Dahlman-Westphal technology transfer (TT) model (1981) includes nine stages: 1.Carry out a feasibility study. 2. Preliminary identification of technology on basis of feasibility study. 3. Carry out basic engineering research, which includes the preparation of technological schemes, models, design specifications of the plant and machinery and technology transferred. 4. Carry out engineering studies to prepare a detailed engineering plan of the facility, including construction and specifications for efficient transmission. 5. Selection of equipment suppliers and subcontractors, formation of a robot coordination plan. 6. Conduct in training, consultations for employees to use in the technology transfer project. 7. Construction of the object (plant). 8. Start of production operations. 9. Introduction of mechanisms for solving operational problems [11].

The main weakness of this model is that it assumes that the recipient of the technology will have access to a high level of engineering skills, which may not be.

The Schlie-Radnor-Wad technology transfer (TT) model (1987) offers seven elements that can influence a technology transfer project: 1. A developer who sells technology. 2. The recipient who buys the technology. 3. Transferable technology. 4. Technology transfer mechanism. 5. The environment, which is a set of conditions for the developer and executors of the transfer project. 6. The recipient's environment - availability of skills, attitude and commitment to the transfer project, technological status, business orientation, economic status, stability. 7. Factors of cross-border and international technology transfer (political relations between countries, exchange rates, investment climate, trade negotiations, trade balance, technological level, as well as the status of intellectual property protection regimes) [12].

The seven elements of this model are valid in today's business environment, but its weakness is that it does not offer guidelines for what the recipient of the technology should do.

The Lee-Choi technology transfer (TT) model (1988) involves development research and indicates that the recipient firm must implement a strategy to be able to go through the stages of acquisition, assimilation, and ultimately improvement. According to this model, the firm chooses the appropriate transfer mechanisms depending on the stage of the technology life cycle and its own technological potential. [13].

The Chantramonklasri technology transfer (TT) model (1990) proposes five phases of technology transfer: 1. Feasibility study. 2. Development of technical documentation and design. 3. Engineering design based on technical documentation. 4. Investing in a transfer project. 5. Commissioning and industrial application [14].

After 1990s technology transfer, (TT) models reveals that researchers have attempted to develop new technology transfer model distinguishing from the traditional models developed earlier which mainly focus on TT processes and can be divided into qualitative and quantitative models.

The Durrani-Forbes-Broadfoot-Carrie technology transfer (TT) model (1998) consisting of five stages: establishing market requirements; identification of technological solutions; classification of identified technological solutions; identification of sources from which the technology can be purchased; completion of technology transfer decision. This model identifies the need for a technology transfer project and the need to identify multiple technology sources to provide better choices. [15].

The Bozeman technology transfer (TT) model (2000) focuses on technology transfer from universities and government laboratories to industry. In this model, the key elements of the transfer process are the transfer agent; transmission mechanism; object of transfer (content and form of

technology); recipient; environment (market, demand and non-market factors). Six measures are proposed: market impact, economic development, political benefits, costs and human capital development as a result of devolution [16].

Other examples qualitative models: involving small and medium enterprises in the TT process (model Khabiri-Rasti-Senin, 2012) [17]; study of the market of technological innovations, identification of aspects that need to be improved, evaluation technologies and results of commercialization (model Milskaya-Mednikov- Loginova, 2016) [18]; focus on competitiveness, by identifying technologies in the innovation market (model Medina-Gasca-Camargo, 2019) [19].

Regarding quantitative models of technology transfer, there are not many of them. The Sharif-Haq model of technology transfer is based on the concept of the potential technology distance between the developer and the recipient and states that when the technology gap is too large or too small, the efficiency of technology transfer is low [20].

The Raz-Steinberg-Ruina technology transfer (TT) model shows how a technology leader through technology transfer can help accelerate technological development. The model considers three phases of growth of the technological follower - the initial phase with a high technological gap, the stage of learning and reducing the gap, and the catching-up stage [21].

The Klein-Lim technology transfer (TT) model (1997) shows that technology transfer from leaders can play a crucial role in modernizing the technical levels of follower companies. This model shows, based on empirical data, the need for activities after the introduction of technology, which facilitates the assimilation and modification of the transferred technology [22].

Other examples of quantitative models: measuring the rate of technology assimilation and analyzing factors that promote or inhibit transfer (model Jayaraman-Bhatti-Saber, 2004) [23]; the influences of facilitating factors on TT results (model Hassan-Jamaluddin-Menshawi, 2016) [24]; focus on market scenarios (model Novickis-Mitasiunas- Ponomarenko, 2017) [25]; measuring the productivity achieved through technology transfer (model Hafeez et al. 2020) [26].

The main contribution of quantitative technology transfer (TT) models is in their emphasis on the need to develop the necessary skills that can generate the necessary information for more efficient technology transfer.

The main contribution of qualitative and quantitative technology transfer models of technology transfer is the justification of the need: feasibility study and technology transfer (TT) process approach in planning/implementation of technology transfer projects. An understanding of the environment is also necessary; involvement of the technology recipient from the beginning of the technology transfer project; engineering and project management skills; the stage of the technology life cycle, the strategic importance of the technology for the recipient and the level of intellectual property protection.

The subsequent development has shown that in addition to the power of innovation, which "pushes" and stimulates economic growth, a significant role is been played by the strength of demand that arises in society in response to the development of another innovation and "pulls" generates new needs and social orders for new inventions.

The study of literary sources (Scopus, Web of Science and Science Direct) made it possible to establish 63 models of technology transfer from 1971 to 2020 [27].

Important direction in the development of modern models technology transfer is to expand the ways of technology transfer and the use of open innovations. Examples of this modern model are the university transfer technology model and the scientific organization transfer technology model.

The transfer technology model of the university identifies various factors that contribute to the technology transfer process and that had influenced by the university: funding structures, research structures, legal and institutional environment of the university. Used: joint laboratories between scientific and business circles, Science Park, research contracts, mobility of researchers, conferences, exhibitions, informal contacts in professional communities. All this creates new non-linear ways of technology transfer [28].

A model of the transfer technology of a scientific organization is proposed, which provides for: direct (linear) transfer technology of closed innovations (from creators-scientists); reverse transfer technology (order from the enterprise); transfer of open innovations (through the interaction of the enterprise, scientists and the support of institutional structures at the international, national, branch level) [29].

Technology transfer in the context of open innovation involves the creation and development of an innovation ecosystem (IE) model, which is based on the generation of new enterprises based on technologies developed in universities and institutions/organizations of scientific research institutes. For this, an innovative cluster is used; technological / scientific park with design and software department; technological development center; technology transfer and commercialization center; business incubator; application of business development methods; application of innovative projects and contests of innovative projects; virtual center of Internet technologies services; during life [30].

The term "ecosystem" was introduced to describe an ecological system [31].

However, in the future, the term "ecosystem" began to be used as a development of the "innovation system" (IS) approach and to describe the structure of participants with geographical aspects of knowledge exchange. [32].

A comparative analysis of the "innovation system" (IS) and "innovation ecosystem" (IE) approaches shows that innovation systems were considered as static structures. However, innovation ecosystems are dynamic systems based on a network of participants (partners) who work together to create innovations and new sources of financial support through partnerships in the innovation ecosystem [33, 34].

The innovation ecosystem (IE) has a significant number of different actors and resources needed for innovation. government that creates a policy and regulatory environment to stimulate research and innovation; research organizations / universities; incubators; startups; innovative enterprises; entrepreneurs; investors; venture capitalists; business development specialists, providers of technical services and training and professional development services. The innovation ecosystem (IE) is based on the knowledge economy created through basic research, transfer and commercialization of innovative developments [35, 36].

The components of the innovation ecosystem (IE) can be small-scale or large-scale, interdependent and interact at different levels. Innovative ecosystems provide an opportunity to organize communities of innovative people, combining different visions and ideas, which allows entrepreneurship to be diverse and create new businesses [37].

Implementation of the concept of open innovation in the model of commercialization of scientific results involved: the creation of an innovation ecosystem (IE) coherence with the national RDI strategy, smart specialization strategy; creation of an effective public-private partnership; development of innovative SMEs based on high value. All this contributes to economic growth, export development and job creation; entrepreneurship education; the use of special instruments of state funding for the commercialization of R&D, created at public expense, the use of vouchers for innovation as tools for development [38].

Leading research organizations and universities around the world, rethinking their place and new roles in innovation ecosystems (IE), consider academic entrepreneurship more broadly than the commercialization of research results [2, 5].

The modern view of academic entrepreneurship goes beyond formal academic technology transfer offices, science parks, innovation centers and their participation in the establishment of subsidiaries and pays more attention to new forms of commercialization with a more significant impact on the economy [39].

Modern academic entrepreneurship is been considered an important factor in changing institutional order, social processes and mechanisms that play a significant role in shaping the trajectories of knowledge, the structure of research organizations / universities and their interaction with the market, society, state apply academic knowledge outside academia [40].

The experience of using outbound open innovations positively enhances the results of innovation activities of enterprises and organizations in the face of growing technological turbulence and increasing competition in technology markets. Skillful management of open innovations is crucial to prevent potential risks and gain significant benefits [41, 42].

The practice of applying the concept of "open innovation" to a large number of companies around the world shows opportunities to accelerate their innovation growth and increase profits by reducing the time of introduction of innovations. Given the number of companies that have introduced the concept of "open innovation" in practice, it suggests that this concept has passed a successful market test [43-46].

Open innovation through ecosystems is a key element of the open innovation community. They bring ideas and participate in the development of innovative products and services. Open innovation ecosystems are hubs with networks or communities working around a common goal [47].

Literary studies of clarifying the role of technology transfer within the innovation system (IS) and innovation ecosystem (IE) allowed us to focus on the theoretical proposals of scientists and identify common features of the key role of technology and differences in the description of innovative mechanisms. The results show that the key elements are the general idea that technology plays a key role in driving innovation, the actors that influence technology and contribute to the achievement of innovation-based goals, and the decision-making process that emerges from technology [48].

Thus, an important direction in accelerating the implementation of a significant number of completed or nearing completion of research is the formation of an effective system of transfer of innovative scientific and technical developments using open scientific practice and academic entrepreneurship.

3. Research results

Based on the analysis of theoretical approaches to the development of innovative systems and ecosystems, open innovation, technology transfer, and academic entrepreneurship, a model of the innovation ecosystem of technology transfer "Six Helix" was developed. Such Technology Transfer Ecosystem (TTE) has a multilevel structure international and national partnership for joint activities of the transfer technology, justifying the need for integration of: national state institutions into European research and innovation institutions; national research organizations and universities to the open research practice of the European Research Area; national innovation enterprises to the European innovation space, Fig.1.

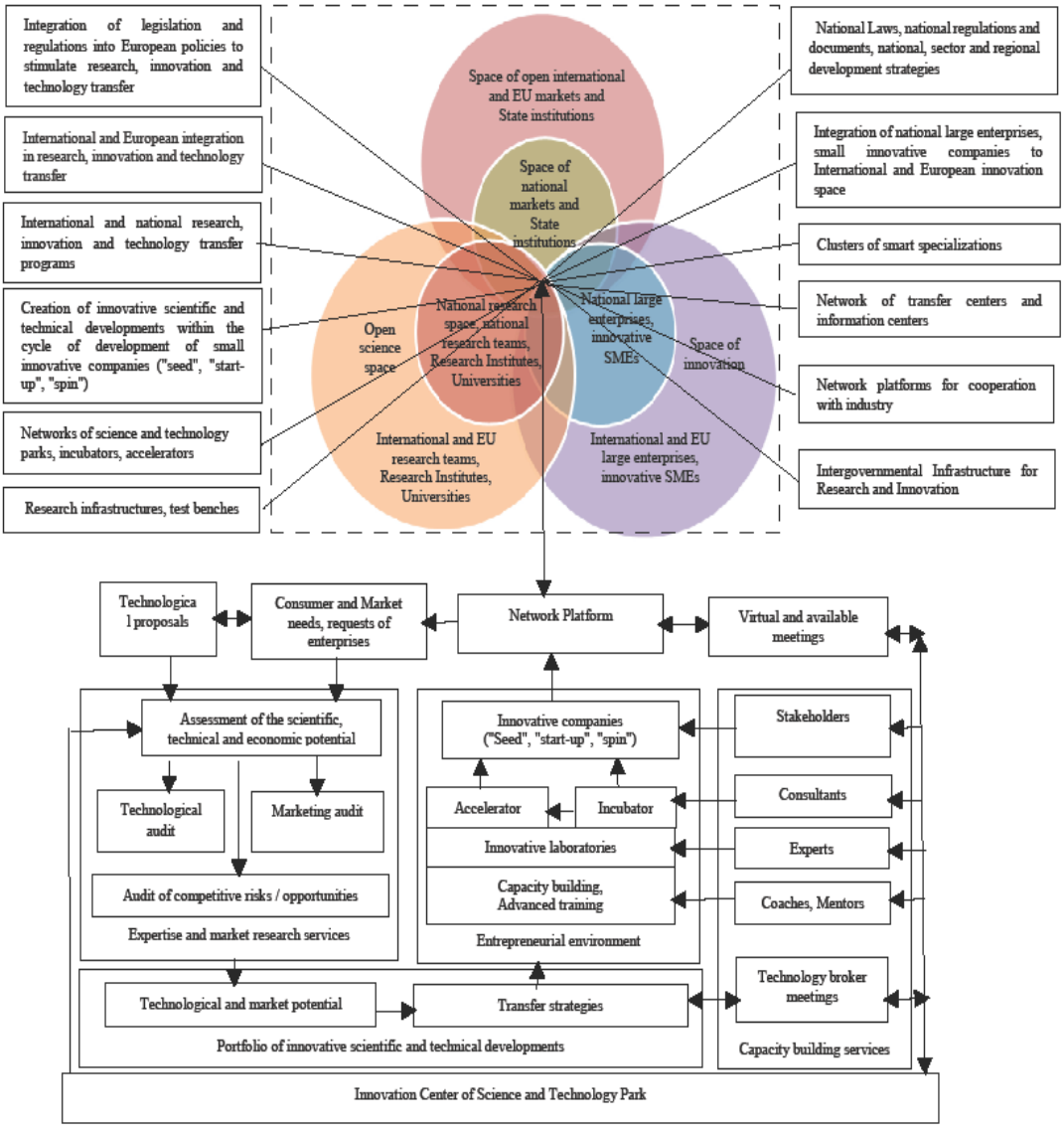

Fig.1 the "Six Helix" model of technology transfer innovative ecosystem.

The first structural level defines the function of building the capacity of international and European integration of national state institutions into European research and innovation institutions by finalizing legislation and regulations to European legislation for creation and development of innovative enterprises.

The second structural level defines the function of building the capacity of innovative scientific and technical developments in external spaces (European Funds and Framework Programs, Networks and Platforms, Centers of Competence, Intergovernmental Organizations) on the transfer of innovative scientific and technical developments that already have a high level of technological and market potential.

The third structural level defines the function of building the capacity of innovative scientific and technical developments within the internal spaces of cooperation and partnership (innovation laboratories, incubator, accelerator) and creation of innovative SMEs (seed, start-up, deep tech startups, spin).

Startups and innovative enterprises differ depending on the stage of development of innovative scientific and technical developments. In the initial stages, research teams can create "seed" organizational forms. In the case where there are opportunities to demonstrate a sample of the

finished product (prototype), research teams can create organizational forms of startups ("start-up"). Organizational forms such as seed and start-ups do not have a market history and large assets and cannot be legally registered or organized into new legal entities.

Deep-tech startups and academic spin-ups are usually created on the basis of research organizations (universities) or their research and development centers based on the results of basic and applied research that have significant market and social influence. Deep tech startups can be the basis for the creation of academic spin. Organizational forms such as "deep tech startup" and "spin" already have a market innovative product and have the ability to produce it in small quantities, but they do not have enough profit to organize large-scale production, and sometimes they need resources to continue R & D to finalize market samples of innovative product. The deep tech startup and spin research teams attract technology specialists, managers and organize interaction with interested and industrial partners / clients in the framework of creating new legal entities. An important stage in the development of small innovative enterprises such as "deep tech startups" and "spin" is the stage of their market expansion, when they are already viable and their innovative product is in demand in the market.

According to the third structural level, the "Six Helix" model of technology transfer innovative ecosystem carries out:

• defining profiles and assessing the potential of innovative scientific and technical developments as a result of technological and marketing audits, analysis of competitive risks / opportunities;

• forming a portfolio of innovative scientific and technical developments, finding partners for cooperation and defining strategies to increase their capacity:

• organization of the business environment within the innovation center of the science and technology park for the creation of innovative enterprises ("seed", "start-up", "deep tech startup" and "spin");

• increase the capacity of scientific and technical developments in the business environment and expand links between research / development teams with stakeholders, partners, competitions of framework and national programs, foundations, technology brokers, experts, consultants, trainers, mentors;

• the use of support services that help research teams build the capacity of innovative scientific and technical developments to negotiate and contract effective transformation of research results into new business opportunities.

The fourth structural level defines functions of information and analytical support of technology transfer within the network platform and network partnership of government agencies, enterprises, research organizations (universities) and other regional, national and international level of cooperation.

The four structural levels of the "Six Helix" model of technology transfer innovative ecosystem provides for the development of cooperation and partnership between:

• National scientific organizations / universities and international, European scientific organizations / universities;

• National teams of researchers of scientific organizations / universities and teams of researchers of international, European scientific organizations / universities;

• Teams of researchers from research organizations / universities and support services of the innovation center of the science and technology park, stakeholders, technology brokers, experts, consultants, trainers, mentors;

• Teams of small innovative companies and international and national enterprises.

This multi-level structure of cooperation creates positive factors for systematically increasing for the absorption / desorption capacity of the technology transfer system, such as direct classic technology transfer, reverse technology transfer, outbound open innovation transfer, which actively uses the inflow and outflow of knowledge for accelerate to sales domestic innovations.

The technology transfer ecosystem involves joining to: international, European and national programs in the field of research and innovation; regional clusters with smart specialization; networks of science and technology parks; networks of incubators and accelerators; networks of transfer - information centers; network platforms for cooperation with industrial enterprises; research infrastructure of the European Research Area; intergovernmental research and infrastructure programs.

The formation of the structure of the technology transfer ecosystem involves the creation and use of innovation center science and Technology Park; network platform; technology transfer office; grant project office; innovation laboratories; incubator and accelerator.

Thus, the proposed "Six Helix" model of the innovation ecosystem of technology transfer involves the use of:

• open scientific practice, which means rethinking international relations and dialogue between researchers and stakeholders to better understand relevant economic and social issues and strengthen the impact of science on the economy and society;

• open innovations, which consists in the development of international cooperation and partnership, on instant transfer in the framework of technology broker meetings, networking and joint development of innovative scientific and technical developments in the framework of projects of international and national programs;

• practices of academic entrepreneurship to build the capacity of innovative scientific and technical developments in the business environment of the innovation center of the science and technology park, which uses innovation laboratories, incubator, accelerator to create innovative SMEs "seed", "start-up", "deep tech startups" , «Spin»).

The application of open scientific practice and academic entrepreneurship in the system of transfer of innovative scientific and technical developments in the model of innovation ecosystem is a key factor in integrating national scientific organizations and universities into the European and international open research space. Integration national innovation enterprises into the international innovation space, markets and determine the place of the national scientific and technological base in the global and European environment.

4. Conclusions

An analysis of important technology transfer models developed over decades and used in academic entrepreneurship to plan and manage technology transfer projects is presented.

It has been established that most models of technology transfer involve the use of a direct (linear) process of technology transfer. However, there are few models of technology transfer in the context of open innovation.

The modern view of academic entrepreneurship goes beyond the traditional framework and pays more attention to new forms of commercialization with a greater impact on the economy, social processes and mechanisms.

The experience of using outgoing open innovations positively improves the results of innovation activities of enterprises and organizations in the face of growing technological turbulence and increasing competition in technology markets. This encourages the simultaneous use of technology transfer systems and innovation ecosystems.

Based on the analysis of the development of technology transfer models, the concept of open innovation, innovation systems and innovation ecosystems, an approach to effective technology transfer in the conditions of the development of the innovative economy is proposed. The proposed approach is based on responsible partnerships and initiatives, which allows for the formation of an effective technology transfer ecosystem that can be useful for universities, research institutions and society. This approach develops mutual trust and long-term strategic partnerships between research institutions/universities and industry.

The socio-economic importance of state-funded scientific and innovative activities is increasing, and the need to increase funding of scientific and innovative activities using mechanisms of public-private partnership, which contribute to the use of research results, including the creation of new innovative companies, is substantiated.

The proposed multi-level "Six Helix" model of technology transfer innovative ecosystem, which is been based on the generation of new innovation enterprises based on technologies developed in research institutes/universities and use direct classic technology transfer, reverse technology transfer, outbound open innovation transfer.

Successful implementation of the proposed the "Six Helix" model of technology transfer innovative ecosystem can lead to a number of benefits for the economy, society in general and, in particular, at the regional level

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