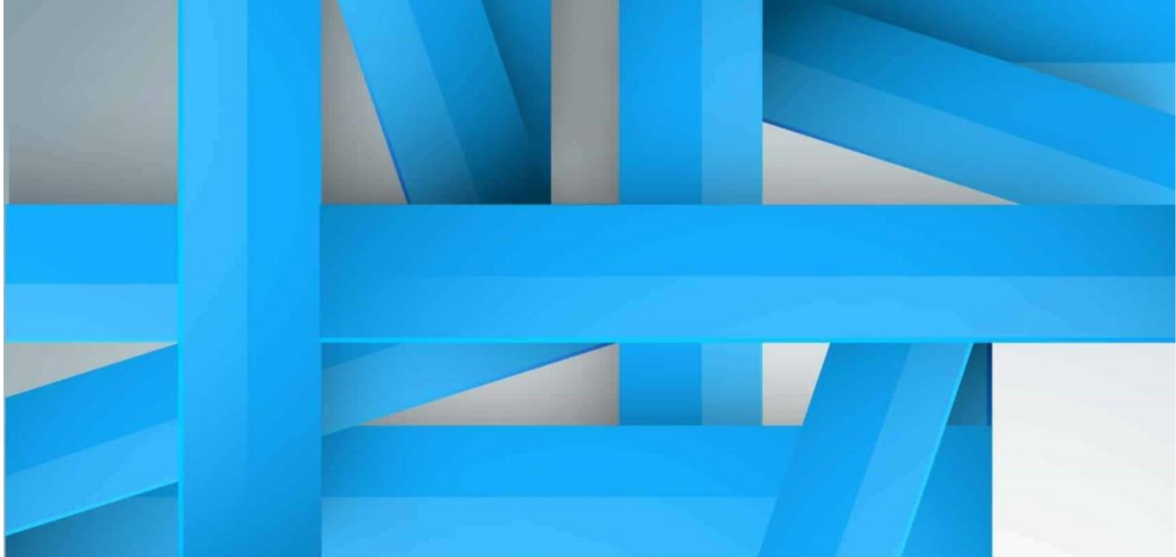
2021

University and Business Interaction in the Concept of Innovation development



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IJSRP INC.

Publication Partner:
International Journal of Scientific and Research Publications (ISSN: 2250-3153)

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www.ijsrp.org

ISSN 2250-3153

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Preface

An innovative economy is based, first of all, on the effective interaction of the scientific and educational sphere and the business environment, free flow of innovative ideas, active commercialization of developments in order to constantly update and develop the domestic economy through new technologies. The monograph examines the issues of building a national innovation system in the Russian Federation, the impact of integration processes between universities and business on the development of innovation and the importance of university science in general. The main trends in the interaction of business structures and university science are stated, methodological approaches to assessing the effectiveness of various forms and mechanisms of interaction between universities and business structures are presented, and the author's method of calculating the effectiveness is proposed.

The book is intended for graduate students, students, students of the retraining and advanced training system, as well as readers interested in the modern problems of the country's innovative development.

Publication Partner:

International Journal of Scientific and Research Publications (ISSN: 2250-3153)

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Publication Partner:

International Journal of Scientific and Research Publications (ISSN: 2250-3153)

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Publication Partner:

International Journal of Scientific and Research Publications (ISSN: 2250-3153)

INTRODUCTION

The transition of the Russian economy to an innovative development trend and the implementation of the import substitution strategy in high-tech knowledge-intensive industries of the industrial and industrial complex naturally predetermine the need for an in-depth scientific and practical study of the priority function of universities in the innovative development of Russia.

In modern conditions, universities are becoming territorial centers of innovative activity. The activities of universities are aimed both at generating new knowledge and building personnel for the new economy and at organizing work to transfer this knowledge for business purposes and attract extra-budgetary funding sources. The issues of effective use of the existing innovative potential of the university, the establishment of interaction between the university, external business structures, and other subjects of the national innovation system (NIS) acquire particular relevance. This is hindered today by the lack of experience in the commercialization of high-tech technologies in market conditions in universities, low demand for high-tech technologies on the part of Russian business, as well as imperfection of the applicable legislation in the field of intellectual property protection.

A convincing argument in confirmation of the timeliness of the problem of effective implementation of the functions of universities in an innovative economy is the fact that the benchmarks developed in accordance with the Concept of long-term socio-economic development of the Russian Federation for the period up to 2020 [1] to facilitate the transition to an innovative type of economic development in Russia increase the relevance of the introduction of the latest scientific developments in the production sector aimed at ensuring the high competitiveness of Russia in the world market, which requires a significant amount of both fundamental and applied scientific research. In the context of the systemic challenge of increasing global competition following the wave of technological change, it necessitates support for innovation and the development of human capital, as well as recognition of the growing role of human resources as the main factor of economic development.

Competitive struggle for a highly qualified workforce, new knowledge, technologies, and competencies are identified as factors that determine the competitiveness of innovation systems in the Strategy for Innovative Development of the Russian Federation for the period up to 2020 [2], in section 2 of which the negative result of an attempt to accelerate the process of integration of Russian innovation systems into the global system and a radical increase in the innovative activity of companies. It can be shown that these disadvantages directly depend on the creation of conditions for the establishment of interaction between science and business. It is fair to say that advanced training for scientists is especially important, since a distinctive feature of scientific activity, in comparison with other types of activity, is its increased complexity, versatility, unpredictability in close connection with the use of various research methods, with the adoption of non-standard decisions in the area's activities that are not fully studied or studied insufficiently [3].

An innovative economy is based, first of all, on the effective interaction of the scientific and educational sphere and the business environment, free flow of innovative ideas, active commercialization of developments in order to constantly update and develop the domestic economy through new technologies. To build an integrated innovation system in Russia, the state policy is being implemented, the following have been adopted and are being implemented: The concept of long-term socio-economic development of the Russian Federation for the period up to 2020; Priority national projects; Measures to stimulate innovation in enterprises (tax policy, the formation of technology platforms and plans for innovative development of state-owned enterprises); Federal target programs (FTP "Research and development in priority areas of development of the scientific and technological complex of Russia" for 2007-2012; FTP "Scientific and scientific-pedagogical personnel of innovative Russia" for 2009-2013; FTP for the development of education).

At the moment, there is no effective integration interaction between universities and business structures in Russia. In these conditions, the development of effective forms and mechanisms for the integration of university science into the NIS will create a continuous production line for new goods and services competitive in the domestic and world markets and ensure the fulfillment of the range of tasks set in the program documents of the Government of the Russian Federation.

In the course of the research, the works of domestic and foreign economists were used, investigating the theoretical foundations of the innovative development of the economy, as well as the problems of the functioning of innovative systems aimed at ensuring the sustainable development of national economies, V.V. Glukhova, G.V. Osipova, D.G. Rodionova, V.V. Ivanova, T.L. Kharlamova, Ya.M. Gibner, E.A. Khairova, I.G. Dezhina, I.P. Malichenko, M.A. Borovskaya, B.Z. Milner, N.L. Marenkov, V. Maclaurin, M. Mellone, L. Edvinson, B.A. Lundwall, M. Unger, W. Polt and others.

Such outstanding scientists as A. Smith, D. Riccardo, J. B. Say, J. S. Mill, K. Menger, K. Marx in their works from various angles investigated the significance of technological innovations for society and the economy as a whole, and Austrian economist J. Schumpeter played a fundamental role in the rapid development of the theory of the market mechanism.

The role of universities in innovative development, the concepts of knowledge generation, the key link of which are universities, have been studied by such scientists as A.O. Grudzinsky, E.A. Monastyrsky, M.V. Fedorov, E.V. Peshina, L.A. Ilyina, A.M. Kolesnikov, A.F. Uvarov, E. Perevodchikov, G. Itskovits and L. Leidesdorf.

The mechanisms of interaction between the subjects of the innovation space in Russia have not yet been built, however, the importance of stimulating the activities of the main subjects to increase innovation activity is shown in the works of G.G. Malinetskiy, V.V. Ivanova, A.V. Litvinova, V.V. Kulibanova, M.V. Parfenovai, G.A. Sakaro, L.V. Silakova, D.Yu. Treshchevsky, A.G. Budrin.

Such problems as the assessment of the innovative potential of the university, the assessment of the level of integration of university science in the NIS, and the analysis of the effectiveness of the innovative activity of the university, much attention is paid in the works of the following authors: Ashmarina S.I., Plaksina I.A., Volchkova I.V., Votyakova I.V., Vorobieva E.S., Nedospasova O.P., Fedosova T.V., Morozova T.V., Pavlova I.A., P.V. Efremova, I.M. Romanova, A.A. Noskov and etc.

Due to the fact that there is no systematic approach to the problem of increasing the efficiency and effectiveness of innovation in universities, there is a need for additional theoretical and methodological research aimed at developing relevant practical recommendations for the development of effective forms and mechanisms for integrating university science in NIS Russia.

The information base of the study was formed on the basis of regulatory legal acts of the federal and regional levels of government of the Russian Federation, materials of scientific conferences, official materials of the Federal State Statistics Service and its territorial bodies, materials of annual statistical and monographic studies on this problem, specialized Internet resources, periodic editions; data from annual reports of organizations in St. Petersburg, the results of applied economic and sociological research, as well as the results obtained by the author in the course of his dissertation work.

During the research, the authors achieved the following results:

1. The relationship between the construction of the innovative economy of the state and the development of integration processes between universities and business structures has been proved, confirming the importance of developing new effective forms and mechanisms of interaction that contribute to the active exchange of information, financial and material resources, as well as the role of state regulation of innovation.

2. The increasing influence of universities on the process of formation of an innovative economy, which activates innovative activity within the framework of the national innovation system, was revealed, and proposals were formulated and substantiated to strengthen the role of universities in the context of innovative development of the economy.

3. New forms and mechanisms of effective interaction of the university with business structures and the state on the basis of an open network platform are proposed in order to increase the potential of all interacting subjects and integrate the university's scientific activities into the national innovation system.

4. An organizational model has been developed for the coordination center for promoting innovations, which contributes to the implementation of the proposed forms and mechanisms of interaction and the development of integration processes between the internal departments of the university and external participants, as well as allowing to increase the level of commercialization of university innovations.

5. A method of complex multi-criteria assessment of the indicator of the effectiveness of the interaction of the university with the participants of the national innovation system has been developed, which makes it possible to obtain standardized indicators for monitoring the development of innovative activity and analyzing the effectiveness of the implemented activities.

The working hypothesis of the research is based on the conceptual and methodological foundations, classical and neoclassical scientific and theoretical principles of the economy of innovation, instrumental and methodological tools, and calculation and analytical algorithms for human resource management, in accordance with which improving the process of forming the national innovation system is a priority condition for the effective functioning of the national economy knowledge and progressive and innovative development of the state.

In general, this monographic study is aimed at an audience of researchers and teachers, graduate students and students of legal, economic, and management specialties, specialists in the field of innovation management.

1. THEORETICAL AND METHODOLOGICAL UNDERPINNINGS OF UNIVERSITY AND BUSINESS INTERACTION

1.1. The theoretical substantiation of the universities and business structures integration in the process of implementing innovative activities

When building a knowledge-based economy, it is necessary to develop innovative educational systems and form goal-oriented management of the process of building an innovative infrastructure, increasing demand for innovation from business structures, which, in turn, contributes to the technological modernization of the domestic economy and the creation of adaptation models of interaction between business structures and universities.

The scientific literature interprets the integration of science and education with the business sector as an endogenous process that occurs in parallel with the processes of differentiation and isolation of subjects and acts as a form that connects the interests of various individual spheres of activity by combining the efforts of participants to meet mutual needs at the lowest cost of resources. When integrating, there are not only their own goals for each of these participants but the overall synergistic effect.

Integration is also understood as a special type of economic cooperation, as a process of adaptation of participants in the economic system in the production, socio-economic and administrative-political spheres, through the creation of new united structures with an accelerated trajectory of development, thereby reflecting a synergistic effect [4]. Thanks to the synergistic effect of cooperation between the scientific and educational sphere and the business environment, an innovative economy is formed, and its efficiency and competitiveness increase.

Management of the process of integration of the academic and business environment is understood as the merger of the management system of the academic environment and the management system of the business sector, each of which has already been worked out separately and actually exists, into one single system [5], [6]. In the process of interaction between the scientific and educational complex and the business environment, scientific research is combined with its practical implementation, which is achieved through an adequate set of tools of both parties, motivated to solve joint innovation problems. Taking into account the fact that these subjects function in an institutional environment, it can be assumed that an integrative complex will be built by building new links between the academic and business environment. Scientists in the field of economics rightly point out that the growing integration process between the academic environment and business structures acts as an objective trend in the innovative economy, and also as a factor in its transformation.

During the transition to a new stage of economic development, it is necessary to include scientific research in the area of personal interests and incentives of business structures, as well as to increase the degree of responsibility of the authorities for the development of an innovative trajectory. The emerging institutional forms determine the formation of new institutions in the knowledge generation system, due to which uncertainty is reduced. Changes are taking place in the nature of the interaction between economic participants, a new level of relations is emerging: “power and business environment”, “power and academic environment”, “academic environment and business environment”. Also, there are changes in the behavior of economic agents, and in the relationships between them. Unfortunately, in the current conditions of the development of the Russian economy, it is still impossible to achieve integration interaction. Undoubtedly, new structures of an integration type are emerging that can solve individual problems, but it is rather difficult to determine how sustainable their development is.

The second half of the 20th century is marked by the beginning of the formation of scientific laboratories under developed corporations, scientific and industrial complexes in the process of interaction between science and the industrial environment in developed countries, the spread of financial and scientific and industrial groups that contribute to the creation of high-quality productive forces of society through the combination of material and scientific production [7].

In order to maximize and develop potential, it is necessary to change the construction of a system of connections between the main participants in the innovation process. At the same time, the primary task is to unite the spheres of science and education, due to which the human potential of science, scientific and experimental base will be preserved and developed, and scientific research will be carried out at universities. Thus, the subjects form a system of mutual participation on the basis of mutual relations and competition, which helps to solve the problems of modernization. Today, there are still some discrepancies in the functioning of the scientific and educational spheres, despite which their mutual activity is being formed. The main differences between educational and scientific activities are as follows: licensing; the ability to exist only as educational institutions; many differences in the organizational structure. Integration processes between the power structures, as well as the academic and business environment, should take place taking into account the pooling of all kinds of resources to create an innovative infrastructure. With the interaction of actors in the educational and scientific environment, such capitals as human, social and intellectual are activated, thus creating the necessary conditions for universities to participate in building an innovative environment due to the growth of the innovative potential of universities and associations of scientific activity. For example, American universities represent the core of the national innovation system (NIS). It is US universities that concentrate the bulk of fundamental scientific developments and a significant part of applied research. The educational process in research higher schools is based on research in science by professors with the active participation of students. Thanks to its technologies, the Massachusetts Institute of Technology forms about 150 companies annually, due to which 90% of the region's jobs are provided. Such world-famous companies as Google, Yahoo, Cisco Systems Inc., and others are the "children" of Stanford University.

Based on the analysis of the interaction between the academic and business environment abroad, the following direct and indirect effects of such interaction can be distinguished (Table 1.1.).

Table 1.1. The contribution of the business environment to the scientific and educational activities of higher schools

Direct influence on science	Investments in research and development, as well as in innovative projects implemented by government institutions. The players of the business environment in many OECD countries are constantly increasing the share of funding for these activities of universities, which expands their potential and determines the profile. There are various forms of investment, for example, the implementation of competitive research grants and awards, the search and employment of named professors, or the creation of competitive programs managed by the firms themselves or their intermediaries. Various forms of co-financing or other types of involvement in government initiatives (implementation of joint R&D projects, creation of clusters, etc.) are popular. Among other things, business is involved in basic financial support for universities, for example, this can occur in the form of donations to scientific infrastructure.
Direct impact on education	Business provides support to students in the form of grants and scholarships. Collaborates with higher schools in the professional training of young specialists (in the course of training in internship, helps in the control of scientific works, admission of students on a part-time basis). Participate in the preparation and drafting of educational programs. Invited experts conduct a course of lectures. Promote development through basic funding or even the creation of universities, especially universities of applied sciences or vocational colleges, that respond to specific business needs in a given area (eg technical universities in the Netherlands or “new universities” in Sweden).
Indirect influence on science	Due to the presence of businesses of various sizes - from small enterprises to branches of TNCs, entrepreneurial ecosystems are being formed around higher schools. This factor contributes to the preparedness of universities and their individual members for the implementation of entrepreneurial activities. The motives are the entrepreneurial spirit, the

	ability to commercialize innovations and finance startups, and a focus on the needs of the firm. Business demands can have an implicit impact on the scientific profile of higher education institutions, drawing attention to specific challenges and needs in the future that will need to be addressed.
Indirect impact on education	Educational programs are developed based on market demand. Often, alumni continue to connect with their alma mater (participate in alumni clubs, provide donations), thereby laying the foundation for building a future network of young alumni.

In order for the mutual participation of the main agents of the innovation environment to become more effective, it is necessary to identify their mutual interests, representing certain needs, which can be satisfied by participating in innovative activities. For the business environment, in this case, the scientific ideas of scientific and educational structures, the possibility of providing human capital, the use of the innovative potential of universities to solve production problems may be relevant. In turn, for the academic environment in the process of interaction, the entrepreneurial experience gained can be useful, the quality of teaching will increase, it will also be possible to operate production facilities, conducting scientific developments there, there will be chances to attract additional financial resources, change the laboratory equipment to modern, develop educational programs with a focus on practical testing. The economic system as a whole from mutual integration will gain such advantages as positive effects from the demand for fundamental research and, as a result of the directions of these studies corresponding to the production tasks, the dynamic use of its innovative developments, as well as an increase in the intellectual capital of scientific workers.

In this connection, there are no incentives for economic participants to interact. There are not enough economic incentives, the government's support for the business environment is poorly developed, the appropriate regulatory framework that controls innovation is not built, and the rights to intellectual resources are not always protected. For effective interaction between universities and business structures, it is necessary to constantly work to reduce administrative barriers, increase diversity and facilitate access to financial incentives, tax breaks, and provide institutional and infrastructural support for economic agents (Figure 1.1.).

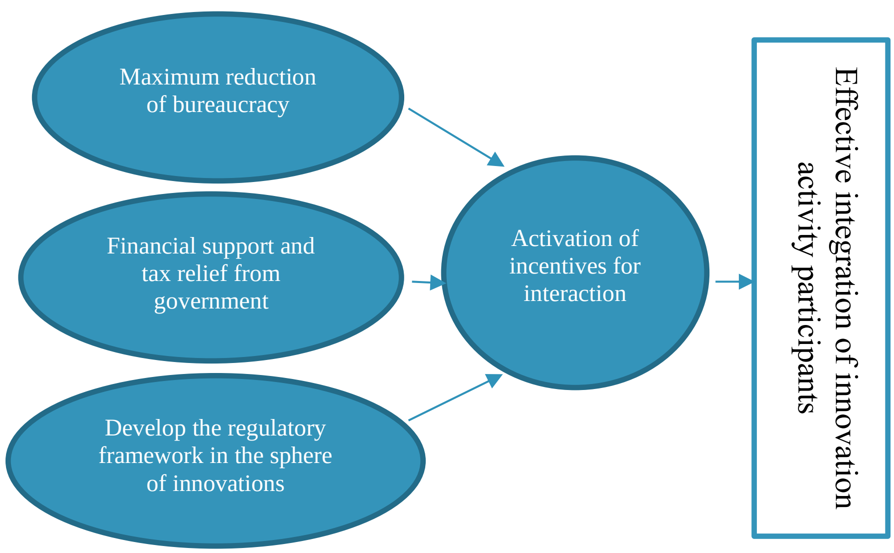


Fig.1.1. Necessary conditions for the development of the state for an effective integration process.

Scientists in the field of economics, studying the integration processes in the "academy - business" system, regardless of the organizational form of interaction, highlight the following problems: an artificially complicated system for building joint activities, which is associated with the established order; a passive attitude towards the participation of leaders of scientific structures, teachers of higher schools and businessmen, which consists in the unwillingness to burden oneself with responsibility for results in the field of management; social attitudes inherent in the country's population (society is used to being wary of innovations); non-observance of administrative and legal conditions (violations of prescribed rules often occur, personal interests are exalted above public). In certain areas of interaction between the scientific and educational sphere and the business environment, the level of importance of issues related to the training of specialists and the provision of material and technical support on the basis of which joint innovative research is being implemented is increasing. To make Russian education at universities prestigious again, it is necessary to raise the level of competitiveness and efficiency of knowledge, as well as to bring the competencies acquired by graduates to meet the needs of business structures.

It can be concluded that at this stage, the absence of a unified scientific infrastructure for firms and higher schools is a serious barrier to innovation since it is the interaction of organizations with research structures and universities that ensures the effective functioning of an innovative economy.

1.2. The influence of the factor of university science on the participants of the national innovation system

Building an innovative economy is possible only if research activities are an integral basis of industrial production and a driving productive force [8]. Despite the enormous damage that the crisis brings to the financial system and the entire economic turnover, it is necessary to form completely new approaches and mechanisms that ensure the effective development of the economy. An important task is the formation of an internal market for high-tech innovative products, which allows large-scale creation of its own high-tech and competitive companies [9].

An innovative economy is based on the achievements of science, the education system, and the skills of workers aimed at creating and distributing intellectual resources [10]. The development of the current crisis situation on a national and international scale confirms the position of academician B.Z. Milner that the creation of an innovative economy is possible only due to the high added value of human intelligence [11]. It is also necessary to create a dynamic information infrastructure that provides an effective process of communication, dissemination, and transfer of necessary information and new knowledge [12]. In our opinion, the formation of a high added value of intelligence presupposes reliance on the development of science and higher education in the country.

Consider the position of Russian universities in the international rankings of the best universities in the world (THE World University Rankings), which is a global study and has become one of the most influential global university rankings. Together with the accompanying ranking of the best world universities, this ranking is calculated according to the methodology of the British publication Times Higher Education (THE) with the participation of the information group Thomson Reuters. According to estimates by The Times Higher [13; 14], among the 200 best universities in the world in 2015-16. there was only one Russian university - Moscow State University. M.V. Lomonosov, taking 161st place. At the same time, this international rating of the year included 63 higher schools in the USA (taking 14 places in the top twenty), 34 - Great Britain, 20 - Germany, 12 - Holland, 8 - Australia, 7 - Canada and Switzerland, 5 - France, 2 –Japan.

The turnover of the market for science-intensive products is increasing every year, putting the innovative sector in first place in a market economy. The formation of the NIS is becoming an integral factor in maintaining the state's national competitiveness. In the process of creating a national innovation system, great attention should be paid to the role assigned to higher education institutions, the purpose of which is to train students (create national human capital), conduct research and innovation. The emergence of many problems associated with a sharp increase in information flow in recent years, for example, solving problems in the management of the financial sector, the lack of traditional approaches in their processing and analysis of big data, which were considered by M.V. Sigova. and Klyuchnikov I.K. in his article [15], confirms the hypothesis about the university factor in innovation. Indeed, it is at universities that research work will be carried out to resolve these very problems, in our example - improving methods and models of working with big data in order to streamline information uncertainty.

Universities as the foundation of the “knowledge triangle” play a key role in filling all of its components. By combining different activities such as education, research, and innovation, higher education institutions often use the “knowledge triangle” as an institutional basis for performing basic functions and creating an organizational structure within the institution. Before assessing the role of universities in different parts of the knowledge triangle, it is worth considering their institutional diversity, manifested in various aspects, such as the implementation of educational and scientific functions, ownership structure, and the degree of institutional autonomy. This characteristic determines their place in the national or regional innovation system. In world practice, higher education institutions are divided into two main categories:

• research universities that provide research-oriented education;

• institutes of applied sciences or university colleges that provide vocational training for students (most often with a narrow specialization) and conduct limited applied research.

Academies of sciences that train Ph.D. applicants and institutions that train specific professions, such as nursing schools, teacher training colleges, or business schools, also fall into this category. Basically, they train specialists of a certain educational level, such as a bachelor's or master's degree. Different types of institutions have different meanings in different countries. Diversity can also be found among institutions of the same category. As an example, we can cite some key aspects: there is a variety in the thematic focusing of scientific and educational activities, resource base, organizational structure, internal management mechanisms, relations with other stakeholders. Given the degree of diversification of higher education institutions, the increase in the effectiveness of universities' participation in the knowledge triangle is due to the flexibility in adjusting policy measures to a specific institutional configuration. Universities differ from other institutions of higher education in that they develop at least two components - educational and scientific, integrating them through the model of "science-oriented" education. The following key trends have prompted a change in the role of universities and an expansion of the range of their activities:

• in connection with the decentralization of management, strengthening of institutional independence, and the transition to methods of financial support "based on results" and due to the competitive basis, universities have more powers, now they independently allocate resources, set strategic goals, and form a unique scientific and educational profile;

• due to integration into the international community, it became easier to exchange knowledge and experience in the scientific and educational sphere, but at the same time, competition for students and scientific teachers increased;

• by expanding the activities of universities, new innovative strategies, new financing schemes, and related policies are emerging, the concept of an "entrepreneurial university" is being updated.

The concept of an "entrepreneurial university" serves as the basis for a partnership between government, business, and academia. The entrepreneurial university is a modern phenomenon. Given the specific academic tradition, this mission is carried out in different ways in many states [16]. This phenomenon emphasizes the growing role of higher schools in the economy, due to the fact that they begin to play the role of other institutional spheres (government agencies and business structures) [16; 17]. The idea of this concept is based on the fact that entrepreneurship should become the main principle of the organization of universities. Adhering to such a model, organizational and management mechanisms are gradually changing, thanks to which universities are consolidated in the status of autonomous and strategic participants in the innovation system. This institutional transformation depends on three key components [18]:

• Regulatory - establishes the legal framework, governance mechanisms, and monitoring systems;

• Normative - realizes the functions of universities based on the expectations placed on them, dominant social values, external context, established agreements, and standards;

• Cultural-cognitive - rooted the entrepreneurial role model in the mentality of the research and teaching staff.

The entrepreneurial component in the activities of higher schools increases depending on the degree of institutional autonomy, distribution of financial flows, management mechanisms, and the surrounding entrepreneurial ecosystem. The transformation of higher schools into entrepreneurial structures occurs under the influence of exogenous and endogenous factors. Various external shocks, for example, the economic crisis of 2008 and the large-scale social challenges associated with it, act as exogenous factors. In order to overcome them, extraordinary solutions based on knowledge and innovations are needed, for the creation of which universities are responsible. Endogenous factors are understood as internal transformations of universities - their organizational structure, strategic goals, or "bottom-up" coordination of the services of departments, including events, etc. Due to the variety of exogenous and endogenous factors, various types of "entrepreneurial universities" appear, which are divided on the basis of their structural features (mission, strategy, organizational and management model, personnel policy, financial resources, infrastructure, location, and environment).

There are four characteristics of universities - scientific-entrepreneurial (research-preneurial), techno-entrepreneurial (techni-preneurial), innovation-entrepreneurial (inno-preneurial), commercial-entrepreneurial (commerce-preneurial). Their classification is presented in table 1.2.

Table 1.2. Classification of "entrepreneurial universities", [123]

Reference point	Characteristic	Examples
Science	• Focus on knowledge creation and science excellence • Have a traditional academic organizational structure (departments / faculties) • Receive a significant share of public investment (basic and competitive basis) • Often have their own large research infrastructures • They are distinguished by their desire to get external investment, which motivates to implement socially oriented programs, to develop links between science and business structures for possible commercialization. Academic specialization and the reputational component of higher schools act as a resource base, and implementation mechanisms are determined by project initiatives, (joint) research centers and specialized units responsible for business relations and technology transfer.	• Stanford University, USA • Munich Technical University (, Germany • University of California at Berkeley, USA • Catholic University, Chile
Technologies	• Focus on applied research while maintaining a strong share of government funding • have close ties with specialized sectors both on the level of institutions, and at the level of staff, which is the direct supplier of knowledge) • Special attention is paid to intersectoral mobility (availability of specialized training programs developed in conjunction with business, entrepreneurial education, training in the workplace) • Characterized by a high level of involvement in regional life	• University of Joensuu, Finland • University of Waterloo, Belgium • Hamburg University of Technology, Germany
Innovation	• Pay great attention to innovative services and business solutions • Are characterized by a flexible structure that allows them to adapt to changing market conditions • Have a high share of private funding, also for vocational schools • Emphasize incentive mechanisms on innovation and entrepreneurship • Carry out knowledge transfer and commercialization, provide services and consultations for business • Typically located near large urban areas and in clusters	• University of Joensuu • University of Waterloo • Hamburg University of Technology

Commerce	• Focus on the commercialization of innovative products and market products in specific high-tech sectors • Differ in close ties with the business environment, organizing joint projects and ventures • Are characterized by business units as a key component in the infrastructure of universities (commercial departments are formed; business incubators and technology parks are created) • Particular importance is attached to the financing of projects that are market-oriented • Use a managerial approach to management • Pay attention to public relations and marketing	• University of Twente, Netherlands • Bandung University of Technology, Indonesia • Waseda University, Japan

In practice, many universities can simultaneously be attributed to several of the listed characteristics due to their multifunctionality, which is due to such factors as the development trajectory, management structure, operating environment, and organizational culture.

Another significant aspect is associated with the expansion of the social role of higher schools, which makes it possible to define them as “socially oriented” (civic) or “involved in public life” (engaged) [19]. Universities in this are the providers of public goods, on the basis of which it is necessary to assess not only the volume and quality of the results of their scientific and educational activities but also their significance for society. In particular, this concerns the creation of knowledge for solving the social problems of an aging population, ensuring sustainable reproduction of energy, developing solutions for “smart” mobility, etc. “Socially oriented” universities also include the function of providing equal educational opportunities to all social groups. They are usually aimed at the local environment, while the direct effects of their activity are manifested at the regional level. A “socially oriented” university makes a special contribution to the “knowledge triangle” system, which is presented in Table. 1.3.

Table 1.3. The functionality of a "socially-oriented" higher school within the framework of the "knowledge triangle", [152]

Channels responsible for communication	Characteristics
Education – science	Practical application of the latest scientific knowledge in the educational process; attracting young specialists to research projects based on the competencies of higher schools and contributing to the solution of a wide range of problems in cities and regions
Education – Innovation	Involving students in projects commissioned by the state or the business sector and allowing students to apply the skills acquired in their specialty, as well as get credit for the work performed. Through participation in educational activities, external communities benefit from the experience of students
Science – Innovation	Focus on solving complex problems; conducting research commissioned by potential consumers, the results of which change the life experience of people

The concepts of “entrepreneurial” and “socially oriented” universities are based on an expanded understanding of the role of universities, which goes beyond research and educational activities, based on appropriate organizational changes. However, there are some contradictions between these models, since the orientation towards entrepreneurship, modernization, pragmatic allocation of assets to achieve a commercial result sometimes runs counter to public goals, which often seem unrealizable in the short-term. But through an innovative and flexible approach, the university can combine “entrepreneurial” and “socially oriented” models, gaining additional benefits from the use of creative resources to develop new solutions.

Unger M. and W. Polt in their study [20] examined the channels, methods of interaction, and political tools that ensure the exchange of knowledge within the academic environment and its transfer to the business environment and society. Some channels serve for third-party actors, for example, companies that transform the products of scientific and educational activities of universities into innovative products and services, while others appear through the active entrepreneurial activity of universities themselves in the process of creating spinoffs, patenting, and other activities, often summarized by the term "commercialization". Often, informal communities develop into formal collaborations. The most common channels for the transfer of knowledge, methods of their formalization, as well as types of political support are presented in Table. 5. The degree of significance of these channels and the possibility of participation in them are determined by two factors:

• institutional characteristics of the scientific and educational sphere, in particular the degree of autonomy and administrative resource of the organization, its branches, and individual employees;

• external environment, which includes potential partner companies, institutions, as well as government policy of financial incentives and other political strategies [21].

Table 1.4. Channels for the transfer of new knowledge, commercialization, and possible ways of interaction

Knowledge transfer channel	Interaction type and tools used
Informal ways to promote	Taking part in conferences
	Building social connections and online communities
	Mobility of students and professors across sectors
	Collaborative publications
Cooperation in the scientific and educational sphere	Cooperation in the field of education: active participation of firms in the writing and implementation of educational programs of higher schools (including for doctoral studies, internships)
	Scientific cooperation: preparation and organization of joint events and initiative projects (for example, research centers, laboratories, cluster programs, platforms, etc.)
	Scientific collaboration on a project basis
	Sharing scientific infrastructure
	Providing consulting services to universities
	Writing collaborative publications
Commercialization and business activities	Issuance of patents and licenses in technology transfer centers
	Formation of state scientific spinoffs and university startups
Other	Co-creation of norms and standards
	Joint development of recommendations for policy-makers, for example through scientific advice or advisory activities at EU level

The above examples of the transfer of knowledge to society usually function separately from each other, while in the “knowledge triangle” model they are integrated with each other. Due to this, the overflow effect occurs, which allows benefiting not only the end-users of scientific and educational results but also the higher schools themselves. Scientists and teachers who implement contract research and joint research projects have significant experience and, in turn, can transfer knowledge about important know-how to students, thus making a certain contribution to their future scientific advancement. Successful start-up experiences also stimulate educational programs to reorient themselves towards entrepreneurship. Thanks to participation in joint projects, the reputation of the university is increased, the high quality of academic science is confirmed, the process of attracting funding is facilitated as well as the search for qualified specialists. We have considered only some of the possibilities: it is worth understanding that their number can be many times greater, taking into account the degree of involvement of specific universities in the transfer of knowledge, in the presence of special stimulating mechanisms, and depending on the reserves of the surrounding ecosystem. Figure 1.2. it is shown how human potential and institutional environment affect scientific productivity, taking into account external factors and flow effects, which are due to the active participation of universities in knowledge transfer activities, depending on their status and potential.

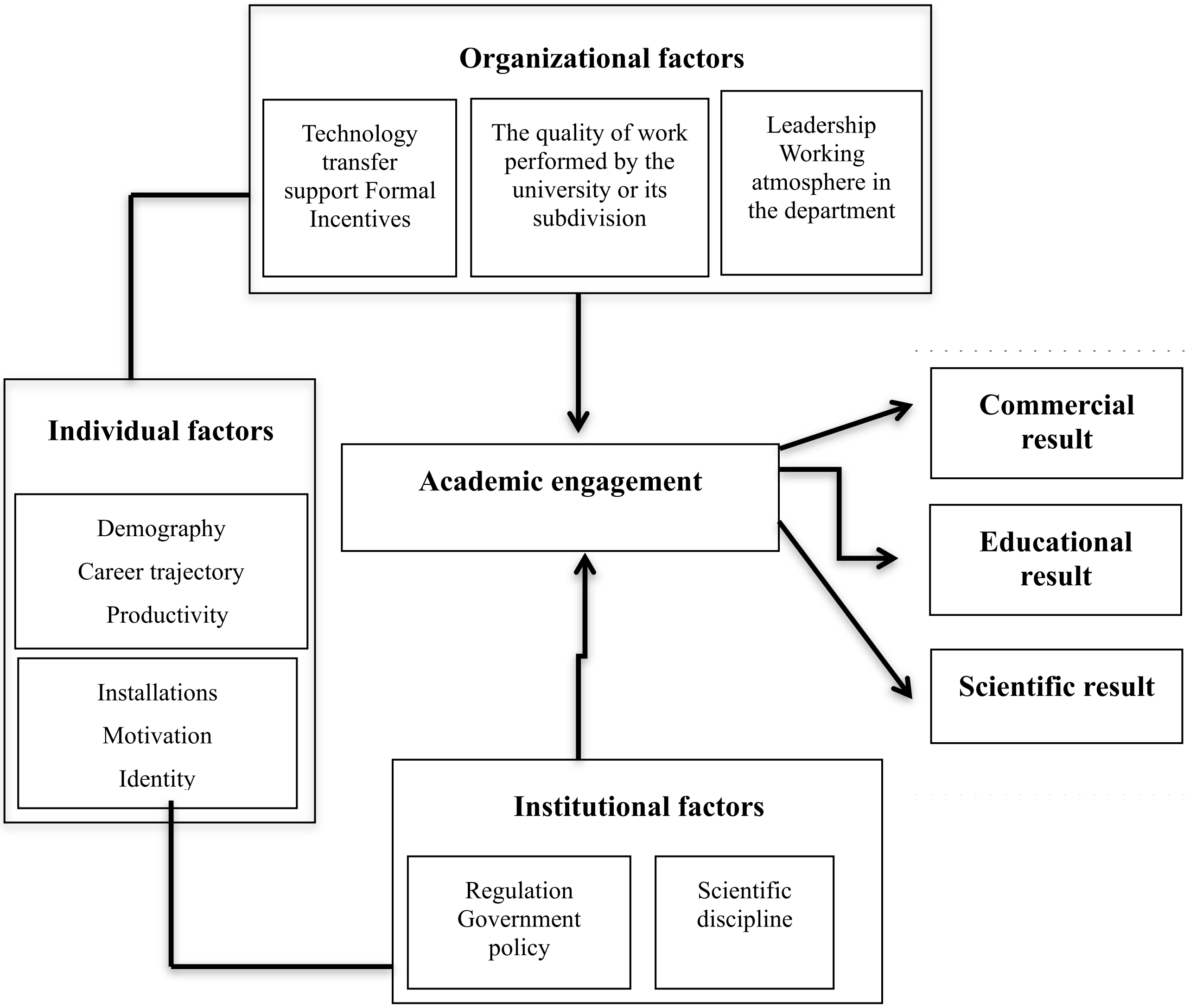


Figure 1.2. Scheme for analyzing the interaction of university scientists with external communities, [141]

In the process of developing measures to support the "knowledge triangle", it is worth considering the interdependence of transfer channels and the internal structure of the university. Higher schools can not only feel positive effects, acquiring new knowledge and increasing their potential, but also feel some problems in the performance of educational and scientific functions. Within the framework of the knowledge triangle, the relationship between business structures and the academic environment, as well as transfer mechanisms, should be not just one- or two-way flows of knowledge in the implementation of specific projects, but as a holistic process of building an innovative environment in which all segments of the triangle are united. Such events usually involve a medium- and long-term collaboration of higher education institutions with partners from the business community and the public sector. An example is the centers that are focused on transforming the results of fundamental knowledge into applied research and turnkey solutions for organizations. Sweden and Austria still hold leading positions in the formation of such structures. Other kinds of tools, such as cluster programs and platforms for development and innovation, are aimed at applied science and innovation. They differ from each other only in those under whose initiative, business structures, or the public sector, scientific projects are carried out with the participation of students and scientists.

1.3. Identification of the main trends in the interaction of business structures and university science

At the moment, Russia is noticeably lagging behind the leading countries in terms of the positions of available innovative developments and their implementation on the market. For example, the aggregate level of innovation activity in domestic companies is about 10%, which is 7.5 times less than in Israel, 6.7 times less than in Germany, and 5.3 times less than in France [22].

In addition, as the events of 2014 showed, the economy of our country is extremely vulnerable to changes in the commodity market and is dependent on external risks. After world oil prices fell threefold, the state once again began to call for change and modernization, proclaiming the transition to an innovative development path as a necessary step. Nevertheless, in the modern conditions of the Russian Federation, innovations practically do not affect the economy, and due to the macroeconomic and institutional environment, there is no stimulation of the innovative activity of enterprises in any form of economic activity. Achievements in this area are insignificant, and indicators in international rankings are extremely low. For example, a special OECD survey of Russia notes that the results of innovation in our country remain low, especially if we take into account the sphere of human resources, scientific traditions, and economic potential [23].

According to the Global Innovation Index, which is published annually by Cornell University, the Russian Federation was ranked 48th in 2015 [24]. In the period from 1995 to 2015, the volume of funding for the sphere of research and development at a constant price fell by 2 times, and if compared with the level of 1990, the decrease is almost 4 times. The number of advanced production technologies that are created annually over the past 5 years is only 700-750 units. New on a global scale include 100-150. Created with the use of patents for inventions, utility models, industrial types of technologies, there were 237 units, which represents 30% of all created. At the same time, only 10-12%, or 50-70 units, turned out to be fundamentally new technologies. In addition, Russia has an insignificant share in the total volume of publications in the world, which are indexed in the Web of Science database, this figure is 2.05% (the country is in 15th place). Also, it should be noted that the Russian Federation on this indicator is ahead of such countries as Italy - 4.18%, Canada - 4.11%, India - 3.93%, Australia - 3.61%, Spain - 3.53%, Republic of Korea - 3.30%, Brazil - 2.53%, which cannot be lobbied by the US corporation. Our national business is almost indifferent to innovation. The economy is characterized by a significant gap between the generation of technology in research and development and its application in mass production. When in 1990 30% of companies were interested in innovations, then by 2013 the figure dropped to 9.7% (for example, in Germany the share of such companies is 62%, in France - 32%, Poland - 23%, etc.) [25].

According to experts, investments in the scientific field from 1990 to 2000. decreased by 54%, and after that, although they increased, but not at all. Domestic R&D expenditures in 2014 reached only 230.8 billion rubles, which is 1.07% of GDP (in 1990, this indicator was 2.03%). Funding for science from the federal budget in% of GDP in 2015 amounted to only 0.56%, and to federal budget expenditures - 2.81%, which is lower than in 2014, respectively, 0.56% and 2.95% ... According to preliminary data for 2016, despite an increase in R&D costs in ruble terms by 10% to 3.5 trillion rubles, in dollar terms, they turned out to be 14% lower than in 2015. At the same time, the share of funding in budget expenditures in civil science continued to decline to 1.9%. The scientific and scientific-technical potential of Russia includes 21 thousand small enterprises of the “science and scientific service” industry, which employ about 140 thousand people. The personnel engaged in research and development amounted to 813.2 thousand people by the beginning of 2015 (53% to the 1992 level), of which 391.1 thousand people were researchers (48.6% to the 1992 level) [26], [27].

A group of American scientists headed by the Dutch researcher Loet Leidesdorff [28] applied an information-theoretical approach to study the knowledge base of the US economy. This approach is based on calculations using Shannon's entropy formula. Scientists have obtained an indicator of the synergy of innovations that directly depends on the effectiveness of interaction between the scientific and educational sphere and business structures. In addition, using this approach, the national innovation systems of the following countries were studied: Hungary [29], Germany [30], Sweden [31], China [32]. Based on the proposed methodology, knowledge-based innovation is capable of emerging through repeated combinations of technological capabilities, any kind of market prospects, existing geographic advantages, or any constraints. Shannon's information theory assumes that the uncertainty of a system with two variables x and y, taking into account the relative frequency p, can be calculated using the following formula:

$$H_{xy} = -\sum_{xy} p_{xy}\, log_2\, p_{xy} \qquad (1)$$

Taking into account the interaction of two variables, the uncertainty of the system is reduced due to joint information, and the entropy is found by the formula:

$$T_{xy} = (H_x + H_y) - H_{xy} \qquad (2)$$

Taking into account the interaction of three variables, we calculate the synergy indicator as follows:

$$T_{xyz} = H_x + H_y + H_z - H_{xy} - H_{xz} - H_{yz} + H_{xyz} \quad (3)$$

The synergy index or entropy is calculated in bits of information (Mbit). The result obtained in this calculation can be either positive or negative. If the indicator is positive, then this means an excess of the historically observed variation, if the value is negative, then redundant information is converted, suggesting the maximum level of entropy, as a result, there is a reduction in relative uncertainty due to the addition of unrealized options to the general system up to this point in time. The increasing number of options for development in the future plays a significant role for the innovation system in terms of its viability. L. Leidesdorff, taking this methodology as a basis, measured the knowledge base of the American economy taking into account the functioning of the triple helix [33].

Russian scientists [30] using this methodology have calculated the knowledge base of the Russian economy. According to the study, the main innovation potential is realized by large companies, while at the small business level, innovation activity is low, despite the high demand for innovation. When the sectors are divided according to the criteria of the intensity of science, it can be seen that production with a high (2,564 companies -0.4% of the total number) and a medium level of technology is not integrated at the regional level. At the same time, one-third of high-tech companies (33.3%; N = 854) is located in Moscow, and another 7.0% are located in the Moscow region. Next comes St. Petersburg, where there are 220 companies (8.6%) of this profile. In other regions, high-tech industries are rare. Based on the calculations, it can be seen that companies with an average level of technology contribute more to integration at the district level than at the national level, while high-tech companies affect the innovation process mainly at the national level (Figure 1.3. And Figure 1.4.).

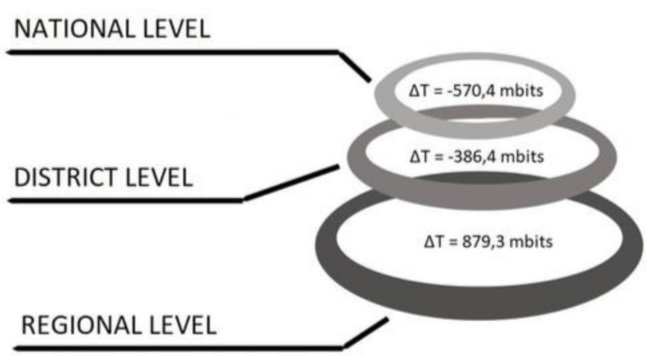


Figure 1.3. Synergy indicators - the contribution of high-tech industries to the innovation system of Russia at three levels

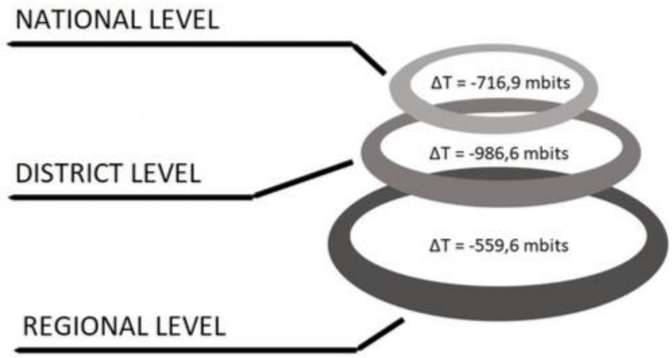


Figure 1.4. Synergy indicators - the contribution of companies with an average level of technology to the innovation system of Russia at three levels

Thus, this confirms our hypothesis about the need to increase the importance of the university factor, which is capable of activating innovative activities at the regional level.

Consideration of the role and importance of higher education in the regional innovation system (RIS) takes place from the point of view of the traditional paradigm of the functionality of the university, but at the same time, new areas of activity are highlighted when higher schools become active participants in the system. Over a long period, the contribution of higher schools to the development of the region has been and continues to be determined as follows:

1. participation in such processes as the generation, diffusion, and use of knowledge with active interaction with the business environment and innovation clusters, implementing scientific and research activities, which has a direct impact on the economic development of the region and causes the growth of technological potential [34];

2. training of qualified personnel for the economy, training and education in a broad sense - an increase in the educational level of the population as a whole [35]. At this stage, one can consider the contribution of higher education to lifelong learning (life-long learning), ensuring the development of regional human resources and raising the regional level of human potential in general. The structures that implement these tasks include institutions of all levels of education (from primary to higher professional).

In addition, today higher schools are expanding their functionality and are considered as important participants and stakeholders of regional development, taking part in:

1. in regional management, since the importance of higher schools in identifying the needs of social and economic regional development and determining the policy of regional development is increasing, and the role of universities in decision-making at the regional level is increasing [35];

2. in increasing regional attractiveness, contributing to the inflow of business structures, financial resources, and human capital to the regions [36; 37; 38; 39], as well as the formation of a favorable innovation environment, allowing the region to develop geographically;

3. in proactive mediation and acting as a mediator of network interactions between different institutions and institutions at the regional level;

4. in ensuring sustainable development of the region [35; 38] at the expense of its educational, scientific, and entrepreneurial activities, which, in turn, is associated with the implementation of both economic and environmental tasks and the tasks of regional development and improving the well-being of its population .

Thus, higher schools in the regional innovation system are considered as drivers of regional development, localizing material and human resources. Here, a significant contribution is made through networked horizontal interactions and communications. Among the requirements for higher schools now are not only personnel training, the implementation of scientific research, but also the implementation of the role of mediators and intermediaries in the RIS.

According to the strategic goal of Russia, set out in the Concept of long-term socio-economic development of the Russian Federation for the period up to 2020, our state intends to achieve a level of socio-economic development that will correspond to the state's status as a leading world leader of the 21st century, being at the forefront of the global economic competition and effectively ensuring the security of the nation and the implementation of the constitutional rights of citizens.

When business structures interact with the sphere of higher professional education and their integration, the indicators of various areas of companies' activities, such as economic, industrial, social, and research, significantly increase.

In recent years, the interaction of higher schools and companies has changed slightly, instead of "consumer" forms, there is a transition to more active types of participation of the existing personnel and experts of the organization in the educational process, among which are:

- development and implementation of curricula and work programs for training specialists by employers;

- organization of various kinds of internships for students in partner companies;

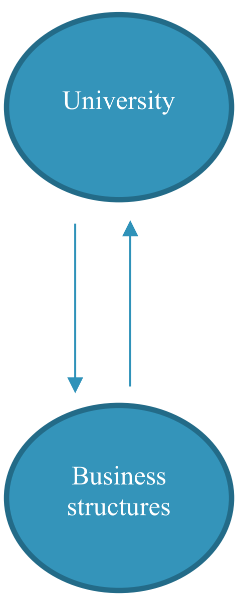
- training of specialists is carried out according to the orders of partner organizations;

- attracting the human and scientific and technical potential of the partner company to the educational process.

Currently, partner companies must take part in the development of educational programs of universities. According to state standards of higher education, the minimum share of practicing teachers for undergraduate programs is 5%, and for master's programs - 7-20%. It is assumed that the involvement of representatives of business structures will significantly improve the quality of educational services and prepare young specialists to perform urgent tasks in organizations.

Thus, taking into account the demand in the labor market and the capabilities of the university, the requirements for young specialists are specified and curricula are developed. Employers who know the business and the field of their professional activity from the inside, understand what functions will need to be implemented by young specialists in the workplace. Therefore, in order to create educational programs most aimed at the formation of those very necessary skills and competencies, it is necessary to carry out functional analysis, describing specific types of work. Thanks to this analysis, changes in technology and organization of work are quickly taken into account, which is the main reference point for university graduates.

Figure 1.5. shows the main issues solved by the university and business structures in the process of designing educational programs.



- the social order and the requirements of the business environment for the graduating specialists of the proposed field of training are determined;

- the goals of the program and the expected learning outcomes for this program are formulated: the "product" that is expected at the end of the training is specified; what types of activities will be able to perform and solutions to what professional tasks a young specialist will be able to find, a list of possible professional actions and the level of their implementation;

- competencies (general cultural and professional) are formulated, which must be formed in the student in the educational process (including profile, reflecting the specifics of the regional aspect and complementing the Federal State Educational Standard);

- the competencies formed in the process of training are correlated with the necessary set of studied disciplines and practices, as well as matrices of compliance of the mandatory competencies and the components of the general education program that develop them are developed.

Figure 1.5. Tasks of universities and business structures in the design of basic educational programs

Among the traditional ways of interaction between universities and business structures, the industrial practice of students is distinguished. In the process of passing the internship, young specialists gain knowledge about the production, organizational and technological process, get acquainted with the documentation of the business structure, gaining experience that is important for future work activities. This interaction has a positive effect both on universities, in particular students, and on the business structures themselves, which get the opportunity to evaluate young, not yet graduated specialists in the process of work.

During the internship, students are given the opportunity to apply their skills and abilities that they acquired during training, as well as to assess the working atmosphere and conditions in a particular organization. At the same time, employers can also take a closer look at future specialists and make an early decision about the possibility of their work in their organization.

Such events and practices have a strong impact on the motivational aspects of future employees and their future employment opportunities. Universities, in turn, fill the gaps in students' practical training.

Targeted training also acts as an effective form of interaction between the university, student, and business structure, which is based on a tripartite agreement, the main condition of which is the mandatory employment of a young specialist after studying at the university.

The state also has a significant influence on the processes of integration of universities and business structures, recognizing the significant contribution of employers to the development of the vocational education system through participation in all stages of student education. In this regard, the standards and regulations of the PLO are reviewed annually. To achieve the goals of integration, practice-oriented training programs for specialists are being introduced.

To ensure a practice-oriented approach to education, it is extremely important to work closely with employing companies. Thus, in the opinion of teachers involved in the preparation of mass specialties, enterprises are more likely to finance targeted training in their educational institutions, compared with the assessment of teachers involved in the preparation of high-tech specialties.

Today in Russia, on the basis of the university, such models of interaction as scientific, commercial, and innovative are being implemented, thus a full innovation cycle is carried out.

Among the most popular models are technology parks and business incubators. Technoparks are understood as organizations on the platform of which research institutes, business centers, manufacturing enterprises are jointly involved in the process of introducing innovations. The main goal of technoparks is to unite various structures and organizations engaged in a similar area of activity to improve the efficiency of joint work, implement scientific research, promote social employment and develop entrepreneurship. The big disadvantage of technoparks today is the high level of costs for its organization. Accordingly, in order for the business to be interested and to benefit, it is necessary to aim not only at the introduction of scientific developments but also the use of marketing tools to promote products, while optimizing the costs of organization and management.

It is possible to solve this problem using the business incubator model, which is a structure that helps organize the activities of aspiring entrepreneurs. A business incubator creates conditions and a favorable environment for startups, regardless of their scope. The Business Incubator advises aspiring entrepreneurs on the legal, financial and organizational aspects of doing business. Complementing each other, technoparks can act as a production site, and incubators can perform managerial and organizational functions.

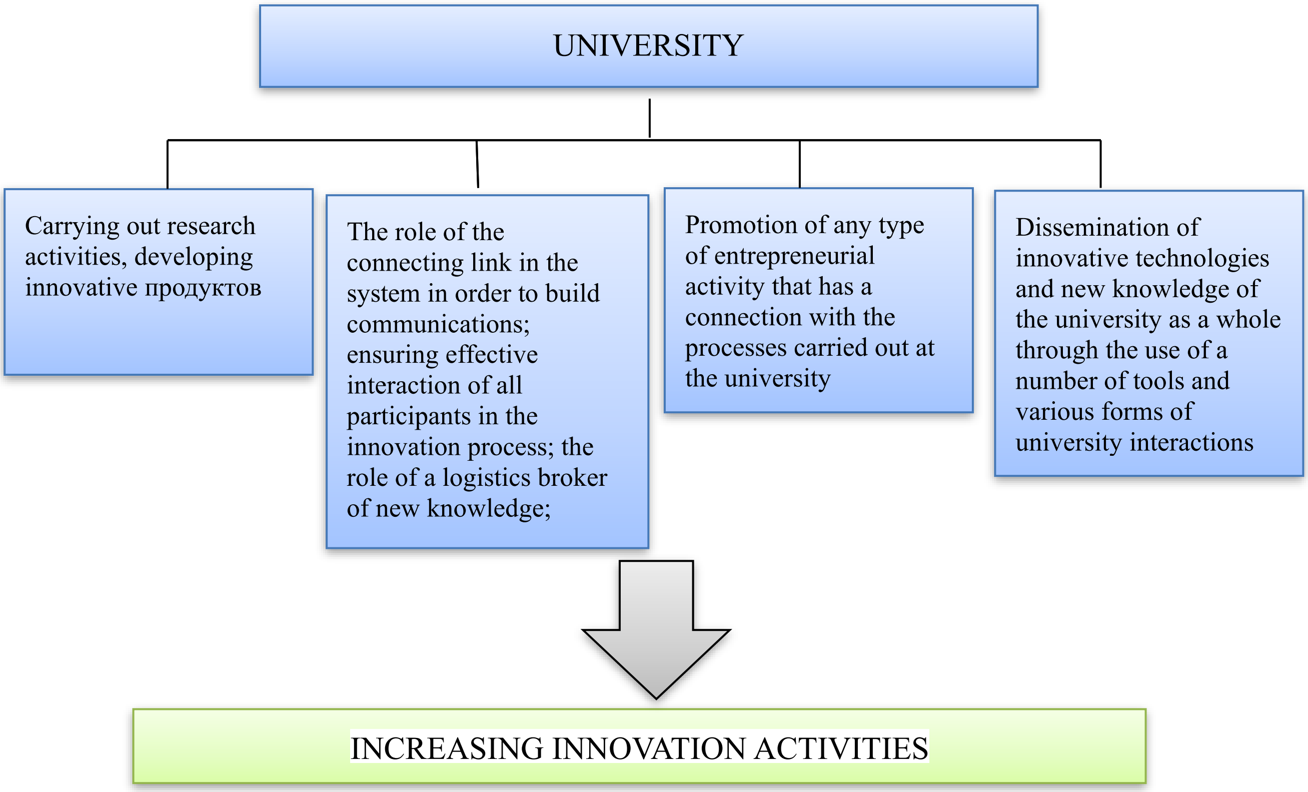


Figure 1.5. Functions of the university in the innovation system

The main tasks at the moment are to strengthen the status of the university as a central element of the innovation system. The regularly used channels of communication between the scientific sphere and production, due to the many differences in their types of activity, are insufficient for the adequate functioning of the post-industrial economy. The university should assume a special role in providing effective communication channels for the scientific sphere and companies. Thus, in the transition to a new stage of economic development, higher schools need to include in their area of responsibility the following areas of activity that determine the performance of their non-traditional functions by universities (Figure 1.5.)

1.4. Methodological approaches to assessing the effectiveness of various forms and mechanisms of interaction between universities and business structures within the framework of the national innovation system

Z.P. Rumyantseva [40] defines the measurement and assessment of efficiency as a prerequisite for the successful and stable functioning and development of the company. The socio-economic efficiency of innovative integrated structures is calculated taking into account external factors that directly or indirectly affect their development process.

The integration of science, education, and the business environment are understood as the close interaction of various scientific institutions, educational structures, and business representing the real sector of the economy, which makes it possible to mutually increase the efficiency of their activities, improve the training of highly qualified specialists, rationally use financial, material and technical, human and other resources ... Integration is considered as an important factor in the development of economic sectors in general, the main goal of which is to ensure the competitiveness and sustainable development of NIS through the effective functioning of scientific and educational institutions, the generation of innovations and the training of highly qualified specialists.

Many researchers studying the processes of integration of the academic environment and business have proposed various methods for calculating the effectiveness and efficiency of interaction [41]. So, to assess the effectiveness of the considered integration of the university and business structures, T.V. Fedosova and T.V. Morozov [42] from the Southern Federal University propose to determine three vector indicators characterizing the development of higher education in the context of interaction with enterprises, enterprise development and mutual development, which is a synergistic effect from the integration of the university and business structures.

Each vector indicator (K1, K2, and K3) is revealed through a group of basic metrics. The first group of metrics includes the number of practice-oriented educational programs, contractual research work, the percentage of employed graduates of the department, the number of programs implemented in cooperation with business structures. The target effect of this group of metrics is to increase the competitiveness of the department in the educational services market. In the second group of metrics, we will place the factors influencing the growth of financial results of the firms participating in the integration and increasing their competitiveness on the local and global markets. These factors include the number of qualified specialists who have been trained in educational programs at the partner department, the implemented innovative developments obtained in the process of implementing business projects and the department, and the joint implementation and participation in targeted programs of regional and national scale are also important. The third group of metrics includes indicators of the formation of basic departments, institutions of additional education, centers responsible for advanced training and professional retraining; indicators of increasing the innovative activity of companies, increasing the investment attractiveness of the environment in which partnerships between higher education and business are carried out; indicators characterizing a decrease in the shortage of personnel and the unemployment rate, as well as those responsible for creating resource potential on the basis of which the implementation of large-scale joint projects is possible.

The level of development of the indicator is characterized by the total measure of the manifestation of all metrics, adjusted by a weight coefficient that determines their significance. Thus, in addition to the pre-collected statistics, expert judgment will also be needed to establish the weights of the basic metrics, measured on a ten-point ratio scale.

$$K = \sum_{i=1}^{3} K_i \qquad (4)$$

$where\ K_i$ - value of vector indicators;

K- integral level of interaction.

$$K_i = \sum_{i=1}^{n} M_i \qquad (5)$$

$$M_i = k \times X \qquad (6)$$

where $M_i -$ base metric value calculated taking into account the weighting factor;

i - number of basic metrics;

k- a weighting factor of the metric;

X – base metric score.

Also, it was proposed to depict a model assessing the level of interaction development in three-dimensional space (Figure 1.6.).

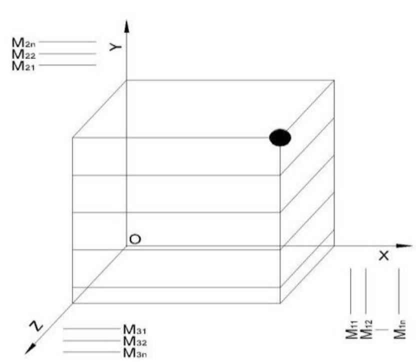


Figure 1.6. Visualization of the model in space, which characterizes the degree of interaction between higher education and business, [97]

Point coordinates are:

$K1 = M11 + M12 + \cdots M1_c$,

$K2 = M21 + M22 + \cdots M2_n$,

$K3 = M31 + M32 + \cdots M3_n$.

Mi= k × X

K_i- vector indicators;

M_i- basic metrics indicators calculated on the basis of a weighting factor;

i - number of basic metrics;

k- a weighting factor of the metric;

X – base metric score.

In order to identify the reserves for increasing the efficiency of interaction between higher schools and business structures, it is possible to use the method of correlation Pleiades, which allows you to determine the level of interaction between the selected indicators. The calculation of the empirical linear correlation coefficients was carried out using K. Pearson's formula.

$$r_{xy} = \frac{\sum(x_i-\overline{x})\times(y_i-\overline{y})}{\sqrt{\sum(x_i-\overline{x})^2\times(y_i-\overline{y})^2}} \quad (7)$$

Where $\overline{x}$ and $\overline{y}$ - the mathematical expectation of a series of x and y.

Pavlova I.A. as a basis for assessing the effectiveness of interaction between higher schools and business. [43] indicators were laid that correspond to the performance of all functions assigned to it by the university at the present stage. Thus, six areas (education, science, business, education-science, education-business, science-business) were identified, within which the required indicators were identified. In the dissertation [44], on the basis of numerous studies in this area, the scientist developed a methodology for assessing the performance of a university in terms of performing an entrepreneurial function and presented a set of criteria for assessing integration interaction and indicators for assessing the effectiveness of interaction between universities and business structures, which is based on a grouping of indicators interaction of higher schools and business structures (Table 1.5.). This model is particularly flexible, as it makes it possible to systematize various groups of indicators and involves transformation in the absence of any data, research objectives and features of the innovation system. However, I would like to supplement this model with indicators related to the implementation of the integration function of universities (education - science - business).

Table 1.5. Comprehensive assessment of the criteria for integration interaction and performance indicators of interaction between higher schools and the business environment

Sphere of interaction	Interaction Evaluation Criteria	Interaction metrics
Educational activities	Implementation of the development and implementation of educational programs in conjunction with higher education; teaching on a temporary or permanent basis for employees of the business environment in high school and high school in the business environment	Number of practice-oriented educational programs; the number of representatives of the business environment who participate in the formation and implementation of educational programs together with university teachers
Educational and scientific activities	Conducting practical training and internships for students; the use by the business environment of the material base of higher education (for example, the use of experimental installations, infrastructure); organization and holding of scientific	The number of students who completed internships in partner companies; number of scientific conferences held by business in conjunction with higher schools

	conferences	
Scientific activity	Publication of joint scientific articles; contract research	Number of articles and projects implemented by the university along with the business environment
Scientific and entrepreneurial activity	Joint research; involvement of higher schools in the provision of consulting services; exchange of new knowledge using communication platforms (round tables, multidisciplinary exhibitions); active interaction based on clusters and other existing technological platforms	The number of developed and implemented innovative technologies that were obtained through the implementation of joint projects
Entrepreneurial activity	Development of startups and the formation of spin-off enterprises (companies that have affiliation or any form of interaction with higher education); participation in the transfer of intellectual rights (licensing);	Number of contracts for intellectual property rights that have been entered into with the business environment and which provide monetary remuneration for higher education
Educational and entrepreneurial activity	Implementation of mentoring, tutoring, organization and simulation of students by the teaching staff to participate in master classes, business trainings aimed at developing entrepreneurial skills of young professionals and employees of higher schools; implementation of additional education	Number of organized and delivered entrepreneurship trainings; the number of employees who have completed advanced training courses or any professional retraining at the partner university
A combination of educational, scientific and entrepreneurial activities	Achieving maximum efficiency of the communication network	Number of implemented joint research programs

The directions of interaction described above are nothing more than organized flows of knowledge that determine the exchange of various resources, such as human, informational, material and financial. Also, when assessing the interaction of higher schools and the business environment, it is necessary to take into account all sorts of informal interactions and the implicit, hidden, knowledge that emerges from this interaction (tacit knowledge), which both parties receive in the process of practical development. This phenomenon is largely associated with the institutional specifics of the functioning of the environment (higher schools and innovation systems in general), where this knowledge realizes itself.

In modern economic conditions, new features of the training of specialized personnel for high-tech enterprises have emerged, which make significant changes in the nature of the work of universities. In particular, at the present time, not mass, but individual targeted training of specialists is required for certain departments of specific enterprises and scientific organizations. At the same time, the task of reducing the adaptation time of young specialists to the conditions of a particular organization is being solved, which is facilitated by a system of practices and internships, the use of contract training, employment and retention of specialists. Strengthening the individualization of training determines not only a radical change in the educational process itself, but also requires strengthening the interaction of the university with enterprises, both in the educational process and in solving production and scientific problems, attracting significant additional funds for organizing the educational process. To fulfill these strategic tasks of joint cooperation, it is necessary to concentrate the resources of interested enterprises, research institutions and universities. It is also necessary to understand that the initiative for integration processes should come precisely from higher educational institutions as from the central agent of the national innovation system.

2. DEVELOPMENT OF THE INTERACTION MODEL OF THE INNOVATION SYSTEM ACTORS ON THE BASIS OF OPEN INNOVATION

2.1. Development of a mechanism for interaction between the university and the innovation process actors based on the open innovation platform

It is also necessary to understand that the initiative for integration processes should come precisely from higher educational institutions as from the central agent of the national innovation system.

The transition of the Russian economy to an innovative development trend and the implementation of the import substitution strategy in highly developed knowledge-intensive industries naturally predetermine the need for an in-depth scientific and practical study of the place and significance of the university in the innovative development of Russia, as well as its interaction with the business environment. According to the analysis of the Global Innovation Index indicators [45] and indicators of university interaction with business (U-Multirank data) [46] it can be noted that in the countries with the highest index of innovative development, the level of interaction between universities and business structures is high. Thus, one of the most important factors of innovative development is the strengthening of integration between the scientific and educational sphere and business.

Nowadays universities become territorial centers of innovation activity. The activities of universities are aimed both at generating new knowledge and forming personnel for the new economy, as well as organizing the transfer of this knowledge for business purposes and attracting off-budget sources of financing. Particular importance is given to the effective use of the existing innovative potential of the university, the formation of sustainable ties and relationships between the university, external business structures, and the state, as well as the integration of the university into the national innovation system (NIS) [47].

At the moment, harmonious interaction between the participants of the national innovation system of the Russian Federation has not been established, the management system for the transfer and commercialization of university science has not been built, innovations are created very slowly and hinder the innovative development of the country's economy [48]. The interaction of universities with external participants in the scientific community in the Russian Federation is developing unstably, since there is no developed interaction mechanism that is recognized as effective for all participants in the scientific environment. At the moment, scientific cooperation is more advanced within each individual organization, which hinders the development of innovations. This situation is caused by the lack of theoretical knowledge about effective external scientific cooperation and the promotion of innovative ideas. The lack of relevant mechanism for interaction between scientific communities also slows down the process of commercialization of innovations. The interaction mechanism should be based on appropriate tools that could activate university-business interaction and facilitate the exchange of knowledge and results of innovation activity (RIA), therefore providing the base for innovation economy formation.

Which form of interaction between innovation system actors is the most appropriate in Russia today? What should be the basis of an effective interaction mechanism? How to measure the effectiveness of the interaction mechanism? These are still unresolved issues on the Russian market that make the study relevant and predetermine the goal.

Open science as a phenomenon is based on two fundamental mechanisms of science organization: openness and sharing [49, 50]. New methods of open science used by research groups at universities, such as open data, open access publications, open protocols, open physical laboratories, crowdsourcing methods or transdisciplinary research platforms, are based on Merton’s principles of science [51], which include: Communalism, universalism, disinterestedness, originality, and skepticism (CUDOS norms). However, scientific practices continue to evolve. Today, open science focuses on the pursuit of “transparent and accessible knowledge that is transmitted and developed through collaboration networks” [52, 53]. New methods of open science and new ways of organizing scientific work using digital platforms, tools, and services for researchers to make science more accessible for citizens, the sharing of scientific results, and the process of creating knowledge more effective and goal-oriented [54]. Understanding the impact of these new open scientific practices on the openness of science is the main goal of ensuring the effectiveness of research systems.

The terms “open” and “closed innovation” were introduced by the American economist Henry Chesbrough [55]. He found that with an increase in the rate of exchange of information flows, the efficiency of using closed business models decreased. Open innovation focuses on the use of targeted inflows and outflows of knowledge to accelerate internal and external innovation [55, 56]. The phenomenon of open innovation has also influenced how universities and research groups conduct research and contribute to innovation processes [57]. The core concept of open innovation is based on collaboration with stakeholders such as government, research organizations, customers and consumers, suppliers, business entities seeking to combine human, financial, material resources, information and knowledge in order to generate innovation with shared values [58]. Therefore, it includes different applications like joint R&D, technology transfer, licensing, open source software, and mass sources (crowdsource) that provide outbound and inbound flow of information [159]. Innovation is a multi-step process [60], which includes various practices at different stages [61]. Over the past 10 years, research and policies in the field of open innovation have been aimed at developing and promoting more input than outgoing methods and processes for creating valuable knowledge [62, 63]. Digital and communication technologies have created new unexplored opportunities and challenges for innovation management in universities (i.e., reliable data exchange, quality control and reproducibility of research methods and results, management of joint research platforms, funding instruments, relations between universities and industry, strategic alliances, by-products, startups, and consortia). In this regard, figuring out how research groups use the new results of open science to generate the results of open innovation is a priority in developing effective policy and management mechanisms for universities.

The acceleration of the frontier of scientific knowledge has coincided with a renewed interest in open science on the part of politicians. Open science norms promote the rapid dissemination of new knowledge and invite broader partners to participate in the discovery of new knowledge. This deepens knowledge, improves its quality and promotes its dissemination (which then leads to a new cycle of discovery and dissemination) [57, 59]. However valuable this broad participation may be, it does not guarantee the subsequent effective commercialization of scientific knowledge. Indeed, the norms of open science can in some way create problems that hinder the commercialization of knowledge.

Open innovation is a concept that can help connect the fruits of open science with the faster transformation and development of its discoveries. Like open science, open innovation involves broad and effective participation and participation in the innovation process [64].

The traditional institutions of open science [64] and the new institutions of open innovation [65, 66] must be adapted, updated, and combined to effectively realize their scientific and innovative potential in the digital world. Universities are a solid foundation of open scientific and innovative practices [67, 68, 69] that contribute to innovation processes at the global, regional, national, and local levels.

Moreover, the open innovation ecosystem stimulates interaction and cooperation between university, business representatives and government, while the high level of interaction leads to accomplishments of innovation activity results.

The active role of the consumer in the innovation process is emphasized in the modern “four-link helix” model proposed by E. Carayannis and D. Campbell [70] based on the “triple helix” model developed by H. Etzkowitz and L. Leydesdorff [71] at the end of the last century. According to the “triple helix” concept, the effectiveness of technological interaction is ensured through close cooperation between government, business and universities, where all components of the “spiral” perform their functions and complement each other. At the initial stage - the generation of knowledge - there is an interaction between science (universities) and authorities (governing bodies). On the next stage - in the transfer of technologies - science cooperates with business (business circles). Market launch is ensured by joint actions of business and government. The four-link model contains the fourth element of the "helix" - civil society as an active consumer and participant in the innovation process, and this is a key factor in achieving success.

In the countries of the European Union, for the active implementation of the theory of open innovation, so-called living laboratories are widely used, whose activities are aimed at supporting the activity of all participants in the innovation process - from manufacturers to end consumers, with a special emphasis on the participation of small and medium-sized enterprises. On the European Network of Living Laboratories website (ENoLL), they are defined as consumer-oriented open ecosystems based on collaborative creativity that integrates research and innovation processes in real life [72].

Finnish researchers of modern innovation research R. Arnkil and co-authors identify four types of models of the "four-link helix", two of which are defined by them as living laboratories [73].

- “Triple Helix + Consumers” is the traditional Triple Helix model, supplemented by a system for collecting and processing information from consumers. It is used in the development of commercial high-tech innovations based on the latest scientific developments. The owner of the innovation process is a firm, group of firms, university or group of universities. Consumers are used only as a source of information.

- "The Firm-Oriented Living Lab" also focuses on commercial high-tech innovation. It can be based both on modern scientific developments and on the adapted use of earlier scientific results and / or knowledge of citizens from the outside. In this case, the owner of the innovation process is a firm or a network group of firms. Consumers in this model act not only as a source of information, they participate in the process of creating new goods and services together with specially attracted experts.

- "Public Sector-Oriented Living Lab" aims to develop community organizations and services. In this case, the owner of the innovation process is a public organization or a group of such organizations. In order for the result of the activity to meet the requirements of customers, it is necessary to regularly receive information from them or have feedback. For this, both traditional methods are used, for example, interviews and dialogues in virtual and real forums, and a specially created environment for citizens - living laboratories. Consumers participate in the development of public services with experts.

- "The Citizen-Centered Quadruple Helix" targets the needs of specific populations. People are the driving force behind what types of new products or services are needed and are involved in their development. The owner of the innovation process can be a citizen or a group of citizens - an "initiative group". The role of firms, authorities and universities is to support proactive [73].

From a philosophy of open innovation to a culture of open innovation, there is a need to overcome the inverted U-shaped curve of the effects of open innovation, which can also be called the paradox of open innovation [74,75]. Currently, during the 4th industrial revolution, the dynamics of open innovation is rapidly increasing with the explosion of the paradox of open innovation, which also means the complexity of open innovation [76, 77, 78, 79]. In this situation, there is a growing need for an understanding of the culture that can control the dynamics of open innovation.

Modern society is used to a culture of cooperation and exchange that is different from the culture of previous generations. Consumers are now more interested in services and experiences than in property. In professional arenas, large communities, often online, have emerged in which people collaborate, often with minimal, and sometimes even no, direct economic value exchange and without traditional hierarchical control [80]. Culture is perceived as a set of living relationships aimed at achieving a common goal - not what you are, but what you do. While definitions of culture vary, it is clear that culture is inherent in the organization, and its top-down values and general assumptions are evident in the behavioral norms and shared experiences of its members. A firm's constructive culture directly enhances cooperation within organizational units within firms and coordination between organizational units of firms, which can indirectly improve firm performance [81]. An innovation culture, that is, a static culture of open innovation, has four dimensions: market orientation, technology orientation, entrepreneurship orientation, and learning orientation [82, 83] A culture of open innovation is built on values such as curiosity, creativity, flexibility and diversity, because an open dimension requires values such as openness, trust, responsibility, authenticity and sustainability [84, 85].

Since open innovation drives the dynamics of innovation and the business models of existing firms, an open innovation culture must be dynamically defined. Open innovation dynamics has two layers: open innovation microdynamics, that is, open innovation–complex adaption–evolutionary change (OCE) dynamics; and open innovation macro-dynamics, that is, market open innovation–closed open innovation–social open innovation (MCS) dynamics [77, 79]. First, entrepreneurship will drive open innovation in the microdynamics of open innovation, because open innovation means a new combination of technology and market across firm boundaries. Entrepreneurs will be interested in moving from a new mix of society and technology to a new mix of technologies and markets across firm boundaries in the macrodynamics of open innovation through new products or services, new markets, new processes, new organizations, or new materials. Second, the internal entrepreneurship of employees of existing firms will stimulate new innovations in these firms. Thus, internal entrepreneurship will include complex adaptation in the microdynamics of open innovation. Intrapreneurs will increase closed-open innovation in the macrodynamics of open innovation, that is, new business projects, increased innovation, self-renewal or proactivity of existing large enterprises, which are mainly based on closed innovation, but pursue strategic goals [86]. Third, the organizational entrepreneurship of the firm itself will facilitate evolutionary change. Organizational entrepreneurship, including corporate entrepreneurship, will drive social, open innovation.

Theories of innovation implementation offer a promising approach to the study of organizational factors that affect effective implementation [87]. In higher education and research institutes, research incentive structures, the search for partners, and the lack of a culture of "openness to business" often impede external collaboration. Thus, while it is in the interest of research organizations and firms to collaborate, they do so less than is necessary. Government intervention helps to overcome such obstacles and reduce costs by subsidizing cooperation. Although the subsidy often only covers the additional costs of the collaboration (and not the actual cost of R&D), this limited financial support can be meaningful for small firms or even for R&D of large companies.

The expected result is triple and complex:

1. The actual outcome of a R&D cooperation project is a "first order effect".

2. A second important effect is a shift in the emphasis of firms and scientists towards more strategic (firms) and more problem-oriented (science) research and development activities.

3. Most importantly, such interventions develop cooperation skills and facilitate learning how to participate in and maintain collective structures (after the intervention) [88].

Such measures usually follow a step-by-step logic: supporting the search for partners and preparing projects, new networks or joint ventures, project implementation leading to expected results and subsequent academic, business and social results. Evaluation of the effectiveness of innovative activities of educational institutions and research centers is carried out using the following indicators:

- Grants & financial instruments;
- Increased R&D investment leveraged by funded projects;
- Newly established or extended networks and centres;
- Scientists and engineers working on joint projects;
- Increased patents / co-publications in specific technology field;
- Enhanced capacity to manage collaboration projects in both science and industry;
- Revenue from contract research or technological services;
- Growth in sales &/or exports of innovative products/ services arising from collaboration projects [88].

It seems to us appropriate to build the interaction of participants in the innovation process on a network basis, as the most promising according to many scientists.

The offered interaction mechanism that based on open innovation platforms is presented in Figure 2.1.

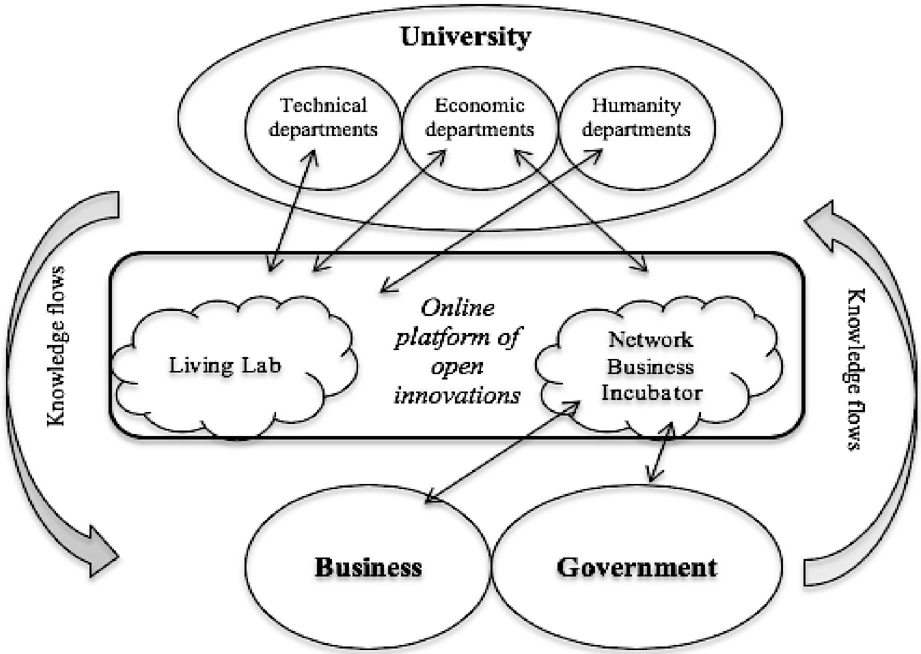


Figure 1.2. The mechanism of interaction between university and other innovation actors

It is possible to involve structural divisions (university departments) in network interaction by creating a "Living Lab", which is an open innovation ecosystem focused on active and permanent cooperation during the implementation of innovative activities due to its openness, exchange of experience and information resources. Such laboratories are actively distributed in the countries of the European Union, transforming at the same time into various forms. In November 2006, representatives of Finland created the central organization of the living lab system in Europe - ENoLL. Despite the fact that in Russia "living laboratories" are not yet widespread, there is already a positive example of the implementation of innovative activities in this format - "Living Laboratory in Tomsk: a smart city with a comfortable environment" [89]. Within the framework of this first project session, work was carried out on the development of project proposals by students, university scientists, specialists in this field, and experts, including international ones, from the international bureau - Netherlands LEVS.

A living laboratory platform is a tool for conducting and implementing innovative projects by combining the intellectual potential of scientists, students, experts, and specialists in certain fields on one online platform.

Within the framework of the living laboratory, economic departments (educational and research units) can act as a driver for promoting university innovation by performing a number of professional functions: market analysis, foresight forecasting of demand for innovations, the search for new customers, advertising campaigns, etc. All technical information will be available online to project teams of technical departments at any time. At the platform of living laboratory there will also be an opportunity to leave applications for studies of interest and request the necessary consulting services of economic departments.

Thus, this platform may turn out to be one of the effective mechanisms of universities' interaction with other participants in the innovation process, contributing to the maximum dissemination of information about existing projects within universities, about promising areas of research for high-tech companies, timely and high-quality implementation of marketing events, and as a result a higher level of commercialization universities innovation.

The creation of a network business incubator can become an effective mechanism for network interaction with external actors of the innovation process.

Through a network business incubator, it is possible to increase the commercialization of developed innovative products and technologies of the university as an independent developer, and in cooperation with business structures through the implementation of network interaction [89].

Such business incubators form an effective organizational structure for the interaction of universities (implementing projects based on the intellectual resources of their employees, as well as the results of basic and applied research) with high-tech business structures (ready to get started projects with a high development potential) thanks to an innovative form of network cooperation.

Virtual business incubators, whose users can resort to consulting and information services without burdening themselves with the cost of renting an office, have recently gained special popularity [90]. In addition, the advantage of a network business incubator over the traditional one is the ability to increase the number of clients by a factor of ten, due to the absence of any restrictions other than the "bandwidth of consultants" and experts providing support to innovative business structures. Considering that the interaction of consultants, experts, and clients of the network business incubator takes place on the basis of telecommunications, the geographical location of the participants does not matter and, if necessary, the circle of interested parties can be expanded [91].

Forming the conditions for interaction, the business incubator is an ecosystem for the implementation of innovative projects, which allows using the potential of all entities of the virtual platform on the basis of integration processes and the integrated use of information technologies [92, 93]. Thus, by combining conditions and resources, a controlled environment is created that allows business projects at any stage to effectively develop. Due to the virtual nature of the network business incubator, the traditional incubation framework, i.e. creative groups that are not registered as a legal entity, an organization can apply for services (services for the development of statutory documents and registration are also provided by consultants). After startups of business structures grow into large developed projects, consulting support for a network business incubator does not end if the company needs it.

Due to the forms and mechanisms of networking between universities and business structures based on information technology, the integration of universities, business structures, including innovative, creative associations and investors, is being implemented, allowing to increase the effectiveness of joint scientific, educational, and innovative activities [94]. A developed software environment is a necessary element for the implementation and use of such forms and mechanisms.

Thanks to open innovations, a wider basis for innovative ideas and technologies is provided, they can be used as a strategic tool to study the potential and growth opportunities, and on their basis higher flexibility, self-organization, and sensitivity to market changes are achieved.

Open innovations are formed within the framework of innovation networks on the principles of a three-spiral model of innovative development, combining the efforts and interests of business structures, the state, universities, using the appropriate institutional conditions and innovative infrastructure, organizing open innovation interaction to create innovative goods that meet the requirements of the market and are in demand by society.

The Living Laboratory is created for the internal cooperation of university's educational and research organizational structures, so that they can share the ideas, projects' and research results. The transparent interaction allows to achieve a synergy effect on innovation activity. The network business incubator is formed for the close and permanent university's connection with business structures and governmental bodies. It facilitates the communication processes and rapid funding search.

The hypothesis of our study is that the online platform of open innovation positively impacts the interaction between innovation system actors – university, business and government, and increases the effectiveness of innovation activity of university.

To assess the state of innovation and identify the directions of its development, the implementation of the mechanism of interaction between engineering and economic science with the actors of the innovation process, the algorithm and technology of which are reflected in Figure 2.2, should be monitored on an ongoing basis.

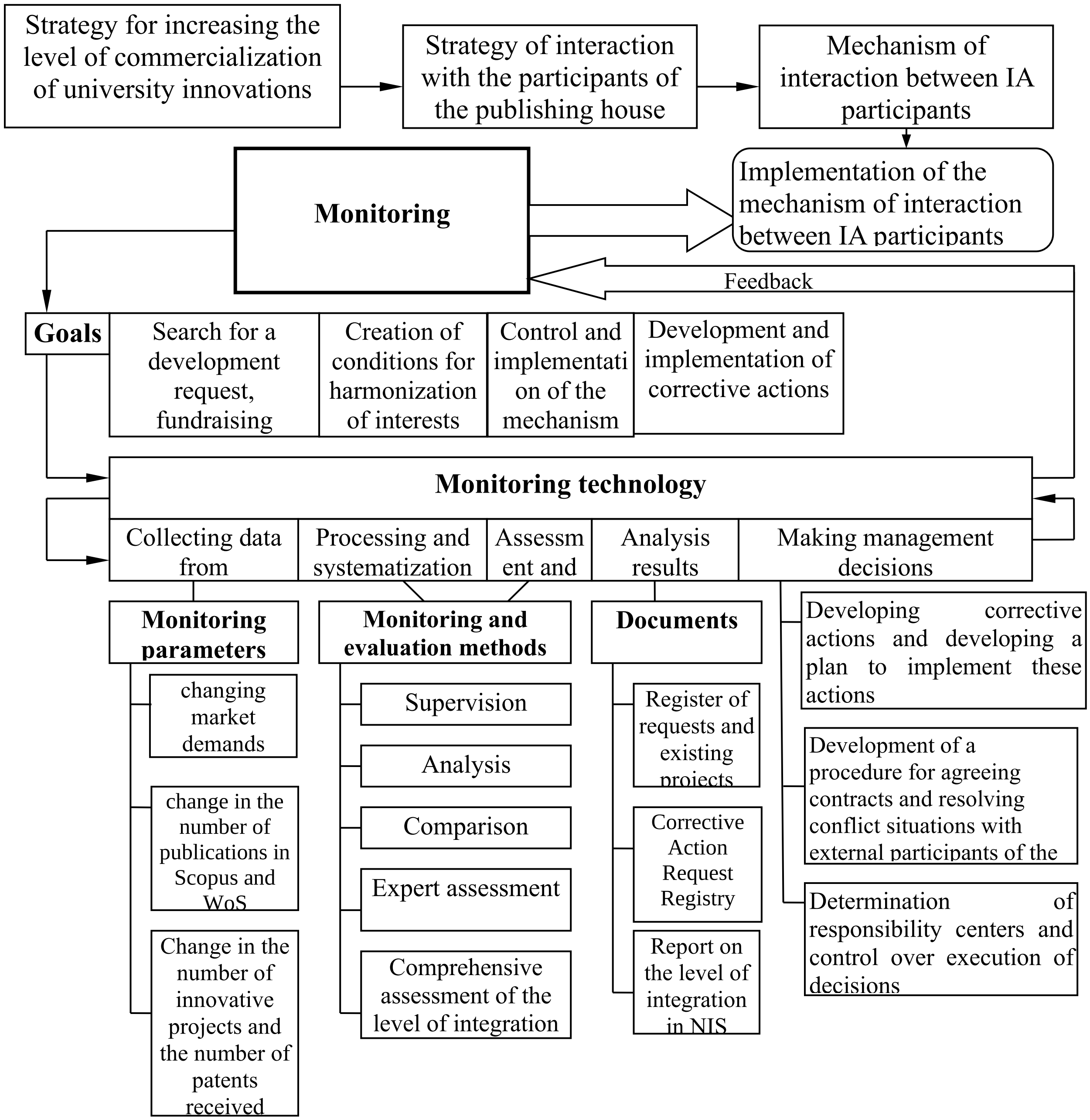


Figure 2.2. Monitoring the implementation of the mechanism of interaction between engineering and economic science with participants in the innovation process

The key directions of the integration of universities into the NIS are set in the Strategy for the Scientific and Technological Development of the Russian Federation, certain state and federal targeted programs, which we considered in the second chapter of the dissertation. The developed organizational and economic mechanism is aimed at implementing additional mechanisms to increase the level of commercialization of university innovations. The purpose of monitoring is to identify bottlenecks in the interaction of internal departments of the university with each other, as well as with external participants in the innovation process. At the same time, monitoring is aimed at identifying and implementing a request for additional corrective measures from all participants in innovative activities. Thus, regular monitoring will make it possible to assess changes and determine corrective measures that contribute to the creation of favorable conditions for the implementation of research and development in accordance with modern principles of organizing scientific, scientific and technical, innovative activities.

Monitoring parameters will assess the effectiveness of scientific networking through changes in design, publication and patent activity.

2.2. Organizational model for a coordination center for promoting the results of innovative activities of the university

When managing the innovative activities of the university, there is a need for a unified structure responsible for the implementation of the results of innovative activities in three main areas: educational, scientific and entrepreneurial.

The set of processes aimed at the systemic interaction of the university with the elements of the NIS affects almost all structural divisions of the university.

This work should be regulated, for which we propose, in order to increase the efficiency of the research and development sphere, to organize within the university a Coordination Center for the Results of Innovation Activity, developed on the basis of the model of the "Council of Integration" of the university and the enterprise, which was proposed by A.V. Fedorova [95]. NIS entities will be able to work in close cooperation with this structure and (through it or directly) with other departments.

The creation of such a center seems to us expedient, due to the absence of a department / structural unit responsible for interuniversity cooperation, which is extremely necessary in the field of research and development, as well as for the marketing of innovative products, which plays a significant role and directly affects the indicators of commercialization. This center for promoting R&D is supposed to be organized on the basis of the Institute of Industrial Management, Economics and Trade to create favorable conditions for promoting innovative products and services of technical institutions, managing the innovative development of the university as a whole and implementing the proposed forms and mechanisms of interaction with the actors of the innovation process.

The organizational model of the proposed university innovation management body is schematically shown in Figure 2.3.

This management is based on the fact that each institution of the university has its own internal structures for R&D management, which are parts of the educational, scientific and management innovation infrastructure (dotted circles). However, a certain governing body is also created - a coordination center, with the help of which the innovative spaces of institutions are united, while their integrity and independence is not violated (rectangle with a solid line).

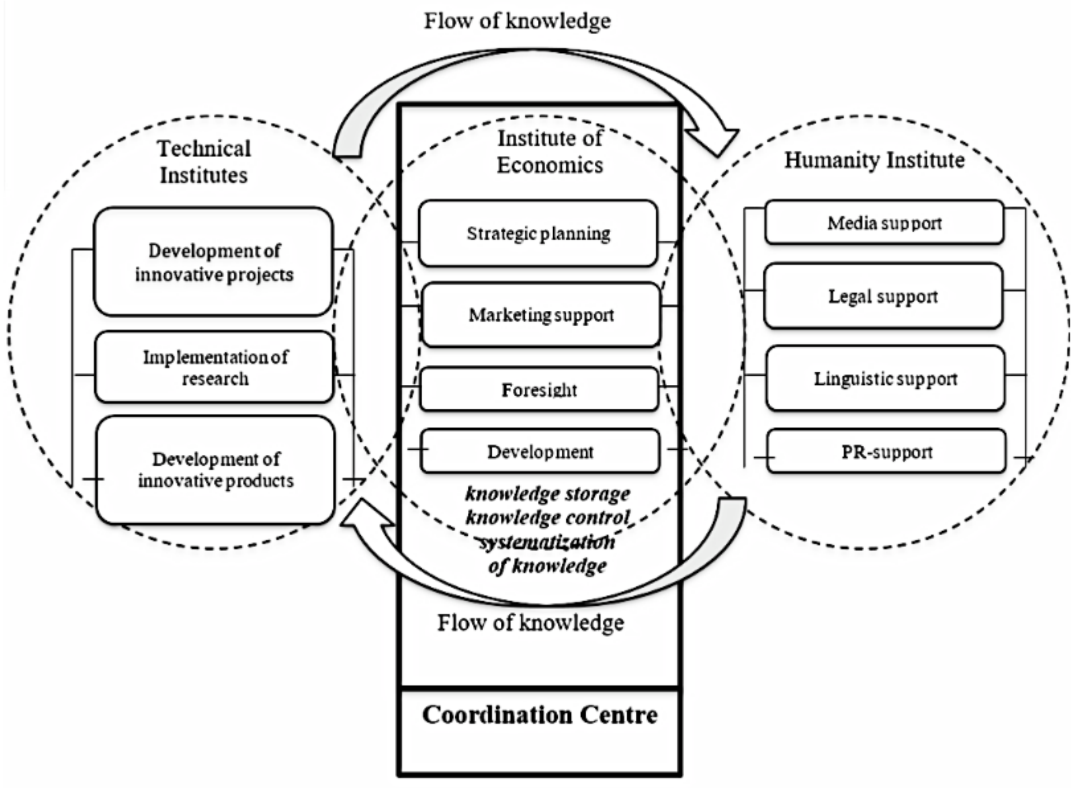


Figure 2.3. The model of Coordination Centre

This management is based on the fact that each institution of the university has its own internal structures for R&D management, which are parts of the educational, scientific and management innovation infrastructure (dotted circles). However, a certain governing body is also created - a coordination center, with the help of which the innovative spaces of institutions are united, while their integrity and independence is not violated (rectangle with a solid line).

In addition, the figure also indicates the flow of knowledge and areas of knowledge exchange among the existing structural units. Each structure performs its own functionality and characterizes the category of human resources involved in the integration processes.

The purpose of creating a unit responsible for the integration processes at the University is to coordinate the processes of generating new knowledge and technologies and implementing their results into practice.

Thus, the Coordination Center responsible for the integration of the university into the NIS has the following goals and objectives, areas of responsibility:

1) organization of the innovation process at the University;

2) coordination of interaction between scientific and educational, research units, structures for the commercialization of new knowledge and external elements of the NIS;

3) development of an entrepreneurial culture through the conduct of activities and entrepreneurship training programs;

4) development of personnel qualifications in the field of design and ID;

5) monitoring of the external business environment;

6) monitoring the results of the ID of the university and the development of measures to improve the methods and means of integrating the university into the NIS.

The functions of this structural unit are:

1) foresight forecasting the demand for innovation;

2) adaptation to environmental conditions through monitoring and forecasting trends in the development of science and technology;

3) collection of data on the results of ID and assessment of the level of integration in the NIS;

4) analysis of the innovative potential of the University;

5) development of standards and regulations for interaction with the business environment, determination of the procedure for managing rights for IPO;

6) involvement of staff and students in the design and publishing house (holding competitions, organizing exhibitions);

7) identification and training of talented personnel (holding competitions, conducting PC programs - acceleration programs);

8) attraction and selection of projects (monitoring of internal R&D and assessment of commercially promising, commercial potential of projects, ideas);

9) organization of work to find and attract partner organizations and external funding (fundraising);

10) data collection and assessment of the level of integration of the university into the NIS;

11) development of specific indicators of achieving development goals, quantitative and qualitative indicators using special methods for assessing the effectiveness of innovations.

The coordination center for promoting the results of innovative activities will contribute to the creation of the university's innovative infrastructure. The creation of an innovative infrastructure at the university is designed to solve a complex problem aimed at creating a special environment that encourages students, graduate students, and university staff to engage, in addition to scientific and educational activities, taking into account modern scientific trends and market demands, as well as innovative and entrepreneurial activities that contribute to the commercialization of high-tech university developments. An innovative infrastructure, consisting of various elements, is ideally capable of supporting the entire innovation cycle of a project - from the inception of an idea to the commercialization of development, solving the problems of analyzing, evaluating and selecting projects at different stages of development, providing the project team with the necessary resources (premises, equipment, etc. etc.) and services (information and advisory support in the field of intellectual property, marketing, fundraising, etc.). One of the main indicators of a functioning innovation infrastructure is the number of results of intellectual activity accepted for budgetary accounting [96].

Thus, taking into account the fact that a weak system for promoting ongoing research and development and, as a result, a low level of commercialization, is identified as a key factor inhibiting the innovation process of the university in question, we propose to introduce a Coordination Center model that can resolve the identified problems and establish integration processes within university. With effective cooperation of the engineering, economic and humanitarian institute, it becomes possible to achieve a significant increase in the number of commercialized innovations created by the technical departments of the university. This allows us to conclude that the developed model of interaction based on the Coordination Center takes place in scientific, educational and entrepreneurial activities, on an innovative basis, created at the university level to ensure the implementation of the Strategy for innovative development of Russia for the period until 2020.

2.3. A methodology of perspective innovation projects selection in the framework of interaction model for innovation system actors

Using the Leydesdorff model (triple helix), it is possible to adequately define and measure the relations between the actors of the innovation system, in particular, the authorities, the business environment, and higher schools, due to which it is possible to achieve synergy or the integral effect of innovation. There is not a single example in the world when the national innovation system (NIS) is effectively implemented in parallel with the principles of the triple helix, and when higher schools are not present at the center of all events. The logic of dependence on universities is simple - only through the efforts of the younger generation can a new economy be built. These people are in only one place - in universities, so this particular place, first of all, should focus on resources for the development of innovative processes [97].

A new stage in the development of society endows knowledge with great power in public life, therefore universities, as the main creators of knowledge, should introduce a new function in modern conditions and act as integrators. By "integration function" we mean the organization of processes of interaction of elements in a complex system to ensure its development. In a particular case, we consider information interaction, which is a process of joint production, exchange, and transfer of knowledge. The University plays the role of a leading participant and organizational intermediary for cooperation between the academic environment, business environment, and law enforcement agencies. The main goal of this cooperation is to unite efforts to solve interdisciplinary problems in the educational and scientific fields, as well as activities aimed at introducing innovations.

Russian scientists [98] have already considered the integration function of universities as a necessary phenomenon in the context of the rapid innovative development of society, due to which all innovative processes occur in the shortest possible time and are highly effective. As an integrator, a university provides its intellectual capital and other internal opportunities for organizational cooperation and also creates external organizational networks of information cooperation. As for the integration function, one should take into account not only the numerous bilateral cooperation with various partner organizations but also, above all, the provision of interaction between partner organizations based on the intellectual base of the university, which operates both as a participant and as an intermediary and catalyst. interaction in general.

However, despite the fact that Grudzinsky A.O., Strongin R.G., and Maksimov G.A. discovered such an important function of higher schools as integrators in the modern economy, we noticed that their work lacks the vision of the triple helix, which is the basis of any progressive innovation system and which must be taken into account when developing a model of interaction between the actors of the innovation process.

According to the Dutch scientist Leidesdorff, innovation is formed as follows: institutional spheres in the triple helix model partially overlap each other, people from different spheres meet, and new ideas appear. Thus, such a model becomes balanced. Institutional spheres fulfill their traditional roles but also acquire new functions.

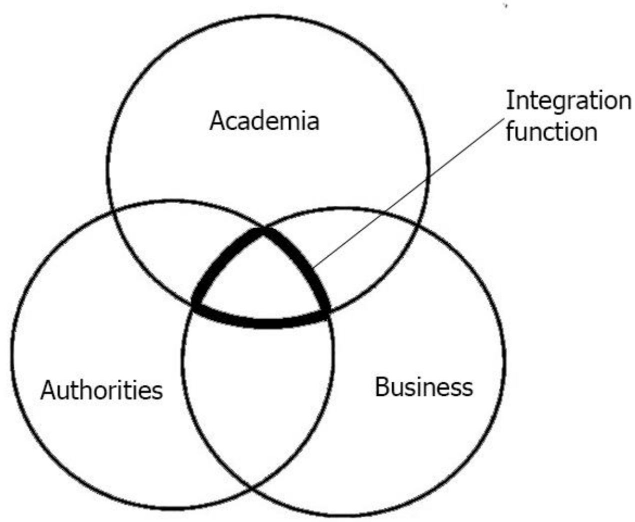


Figure 1.4. The sphere of active participation of the university integration function in innovation processes

We, in turn, would like to demonstrate the cumulative role of the university factor in the process of interaction between entrepreneurial, government, and research spheres, since it is at the borders of the intersection of three spheres that the integration function actively enters into action, provides management and most effectively organizes the relations of actors with each other, which, in turn, allows generating the maximum possible amount of new knowledge (Fig. 1).

Taking the triple helix model as a basis, we propose to build an interaction model of the innovation process actors in the Russian Federation. In our model, the integration function of universities connects the information flow of three dynamic and constantly developing actors of the innovative economy (government - academy - business) by a common thread. The locus of function is located in the center of the model, and the core, or "information genome", encourages all drivers to create multilayer communications, networks, and organizations among the spirals (Fig. 2).

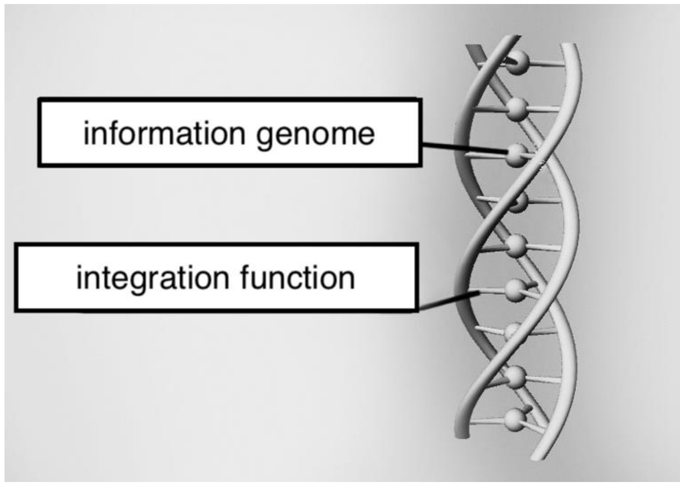


Figure 2.5. The locus of the integration function in the model of interaction between the actors of the innovation process.

Although the spirals of institutional spheres are constantly evolving and transforming new information, the integration function is not lagging but is being modernized and adapted to new conditions, helping to interact with subjects at every level of their development. Universities in the process of implementing the integration function create innovative schemes for the transfer of knowledge based on digital technologies, new methods for calculating the attractiveness of common projects with the industry, thereby increasing the return on investment, universities are responsible for management innovations during the integration process, and also monitor the observance of intellectual property rights.

The university integration function can be interpreted as a flow of knowledge generated and appropriately supported by the efforts of universities. Thus, thanks to the integration function of universities, the most favorable environment for the implementation of innovative activities in general appears. This enabling environment is an innovation ecosystem in which participants in the innovation process interacting with each other have a synergistic effect. Collaborative innovation ecosystems are considered successful innovation ecosystems. A successful ecosystem is based on the organizational structure of the network.

As the main indicator of the effectiveness of the proposed model of innovative actors' interaction, we propose to take, first of all, the number of implemented innovative projects at the regional, district, and national levels. It is possible to increase the degree of innovative development and diversification of the economy of the Russian Federation thanks to the active and permanent use of new technologies developed at different levels and based on scientific developments of a fundamental nature. To achieve maximum results, it is necessary to select scientific developments that are of interest from the point of view of the possibility of their practical application and contribution to the country's innovative development.

The complex tasks of forming and searching for rational ways to implement the results of scientific and technical projects highlight the need to assess their results. Based on this, we propose to develop a methodology for assessing the effectiveness of joint innovative projects, which makes it possible to obtain, in a form convenient for presentation and processing, assessments characterizing the degree of influence of each element of the system on the achievement of the set of goals, taking into account the importance of types of objects and the priority of investment areas.

The selection of the highest priority projects of universities and business is a difficult problem. It is necessary to structure the elements that influence the choice of one or an-other innovative project into groups in accordance with the distribution of some properties between the elements. In this case, the properties of the groups are considered as the next level of the system until the only element is reached - the top, that is, the goal of the decision-making process. Such a system of layering levels is called a hierarchy. Based on the hierarchy, the elements' influence of the lowest level of the hierarchy on the topmost element - the overall goal - is determined.

A.A. Denisov [99] proposed to consider hierarchical structures from the standpoint of information analysis. In this case, hierarchy is identified with a sequential connection of sources or receivers of information. According to A.A. Denisov, any sequential connection is a hierarchical structure in which the number of levels of the hierarchy is equal to the number of consecutive elements in the information chain, and the potential of each level is determined by the probability of achieving the goal by the entire chain, starting from this level and lower in the hierarchy.

Comparison of the criteria among themselves can be carried out on the basis of the method of analysis of hierarchies by T. Saaty [100], using the advantages of paired comparisons. The theoretical prerequisites for the analysis of experts' preferences based on the method of T. Saaty are based on the results of research by such famous scientists in the field of psychophysics as E. Weber and G. Fechner. According to the provisions of the method of analysis of hierarchies by T. Saati, when forming judgments about paired comparisons of criteria between themselves, irritations arise that cause reaction, the values of which are expressed in the form of relations.

Pairwise comparisons are performed by recognizing the least significant of the two criteria, which is used as the unit of measurement. Then, using a scale (Table 1), a number or a verbal equivalent is determined that expresses the superiority of a dominant element in a pair of compared criteria.

Table 2.1. Scale for identifying the relative importance of criteria

Intensity of relative importance	Determination	Explanation
1	Equal importance	Equal contribution of criteria to the goal
3	Moderate superiority of one over the other	Experience and judgment give slight superiority to one criterion over another
5	Substantial or strong superiority	Experience and judgment give strong superiority to one criterion over another
7	Significant superiority	One criterion is given significant superiority
9	Very strong superiority	The evidence of the superiority of one criterion over another is most strongly confirmed
2,4,6,8	Intermediate solutions between two adjacent judgments	Apply in a compromise case
The reciprocals of the numbers above	The number of the less important criterion obtained by comparing the criteria is inferior to the more important criterion	

In the process of paired comparisons, the expert uses the nearest integers from the 1 - 9 scale. We agree with the well-known Russian expert in the field of decision-making O.I. Larichev [101] that the disadvantage of the hierarchy analysis method proposed by T. Saati is the change in preference relations between compared alternatives when introducing a new alternative. Therefore, it is possible to use the method of analysis of hierarchies by T. Saati only to obtain the priority of criteria on the basis of the scale of relative importance developed by him (Table 2.1).

The multiplicative method for the analysis of hierarchies, developed by the Dutch scientist F. Lootsma [102] (professor of the Department of Applied Mathematics and Computer Science, Delft University of Technology, Netherlands), has a methodological rationale that differs from the rationale for the method of analysis of hierarchies by T. Saati, who used the Weber-Fechner law. Lootsma proceeds from the fact that the decision-maker evaluates the stimuli on the one-dimensional desirability axis relative to each of the relevant criteria (Table 2). The method is based on two main points. In accordance with the first, if the decision-maker determines the relationship between two elements of the corresponding level of the hierarchy, then instead of summing the values obtained from comparisons, it is more rational to multiply such relationships. At the same time, F. Lootsma emphasizes that it is the ratios of the compared elements, and not the absolute values, that participate in the calculation. The second provision stipulates that the transition from verbal comparisons to numbers should occur on the basis of some assumptions about human behavior in comparative measurements.

Table 2.2. Scale for revealing the relative importance of elements of one level of the hierarchy

Publication Partner:
International Journal of Scientific and Research Publications (ISSN: 2250-3153)

Quantitative value	Relative importance level
6	Significant superiority
4	Strong superiority
2	Moderate superiority of one over the other
0	Equal superiority
– 2	Moderate subordination of one element to another
– 4	Strong subordination
– 6	Significant subordination

We propose a methodology for selecting priority business and university projects based on the multiplicative method of hierarchy analysis proposed by F. Lootsma [102].

The method of forming an investment program for joint innovation projects of universities and business structures includes seven stages:

Stage 1. It is necessary to define the overall goal of the hierarchy - the distribution of projects in accordance with their priorities. The task of choosing a priority innovation project by a university to achieve a set of goals can be represented in the following hierarchy (Fig. 3).

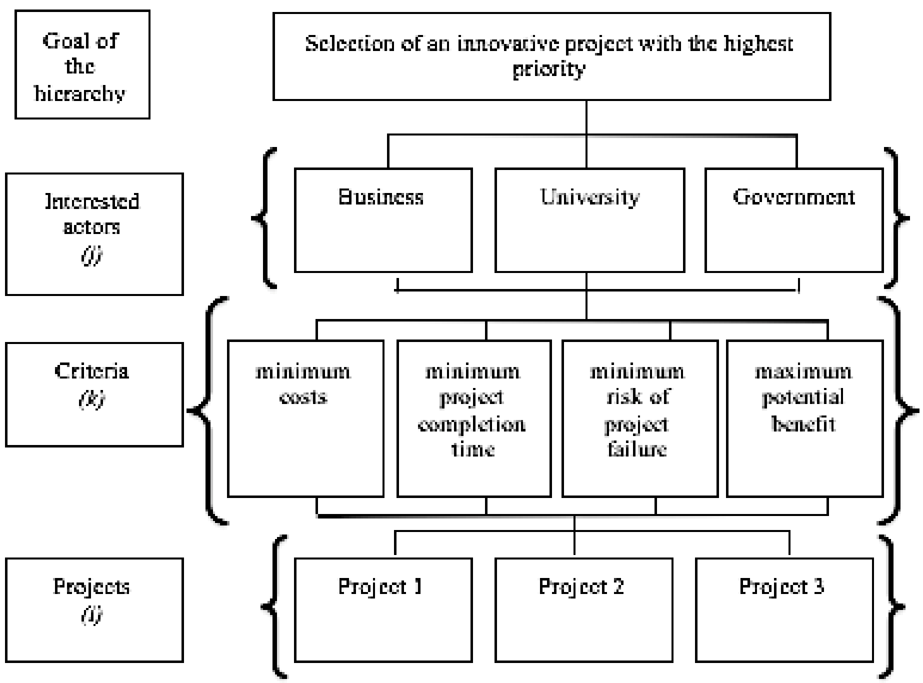


Figure 2.6. Decomposition of the task of assessing the priority of project financing into a hierarchy

Stage 2. The levels of groups of the innovation process actors are formed, interested in the effective distribution of money and labor resources between projects and the achievement of the set goals: 1) universities; 2) business companies; 3) the state.

Stage 3. The elements of the criterion level in the priority project selection hierarchy are determined. We propose to evaluate innovative joint projects of the academic and business environment according to the following criteria:

1) minimum costs;

2) the minimum project completion time;

3) minimum risk of project failure;

4) maximum potential benefit.

Stage 4. The projects themselves are included in the lower level of the hierarchy.

Stage 5. The priorities of projects are calculated based on the multiplicative method of hierarchy analysis. This requires:

5.1. The elements of the matrix of paired comparisons of elements at each level of the hierarchy are filled. The comparison itself should be carried out in an expert way using a scale that reveals the relative importance of the compared elements.

5.2. After that, for all the resulting matrices of paired comparisons of elements of each level of the hierarchy, the a_{rs} indicator is calculated, which reflects the level of superiority of the compared element r over element s according to the element comparison scale (the values of r and s are related to the row and column, respectively):

$$a_{rs} = e^{\sigma_{rs}}, \qquad (1)$$

where σ_{rs}, – quantitative value of the relative importance according to the Lootsma scale (Table 2).

Then you need to calculate the priorities of the compared elements x_r:

$$x_r = \frac{S_r}{\sum_{r=1}^{N} S_r}, \qquad (2)$$

where S_r– geometric mean elements $a_{rs}$by N.

Therefore, using formulas (1) and (2), the following indicators are determined:

1) weight of all interested actors of innovation activity – β_j (influence of the j-th actor on the implementation of an innovative joint project);

2) criteria weights –z_{jk}, denoting the significance of the k-th criterion for the j-th actor;

3) project priorities for all criteria – ω_{ik} (the priority of the project, which reflects the contribution of the i-th project to the achievement of the k-th goal).

Stage 6. Criteria are weighed by interested actors, and then the priorities of projects are weighted by criteria, using formulas (3) and (4).

First, the criteria should be weighed across all actors:

$$Z_k = \sum_{j=1}^{3} Z_{jk} \quad \beta_j \qquad (3)$$

where j = 1, 2, 3 – serial number of the interested actor; Z_k – the weight of the k-th criterion for all groups of persons.

Using formula (4), we obtain the normalized weights of the criteria d_k:

$$d_k = \frac{Z_k}{\sum_{k=1}^{4} Z_k}. \qquad (4)$$

Further, the project priorities obtained as a result of calculations (1) and (2) must be weighed by the criteria weights.

$$p_i = \sum_{k=1}^{4} \omega_{ik} \quad d_k, \qquad (5)$$

where k = 1, 2, 3, 4 – serial number of the criteria; i = 1, 2, …, n – serial number of the project; p_i– the priority of the i-th project, reflecting its contribution to the achievement of all goals.

Stage 7. The final priorities of the investment program of projects (v_i) are determined, taking into account the hierarchy built according to the formula (6):

$$v_i = \frac{p_i}{\sum_{i=1}^{n} p_i}. \qquad (6)$$

Thus, this methodology for choosing the priority areas of interaction between the actors of the innovation process, which makes it possible to implement an effective investment program of priority joint innovation projects of the university and business structures, was developed on the basis of the multiplicative method of analyzing hierarchies as a multi-criteria approach to the analysis of complex problems. The proposed methodology allows for the implementation of an optimal project financing program, taking into account the interests of the university, business structures, the interests of the state, as well as the goals set for the main actors of the innovation process.

Application of the developed methodology within the framework of the interaction model

We would like to show that thanks to the introduction of this methodology within the framework of the innovation actors interaction model, the flow of new knowledge, projects and developments are controlled and carefully processed during the transition from the regional level to the district level, and then from the district to the highest level - the national level, thus at the federal level, there are the most priority and most contributing developments (Fig. 3).

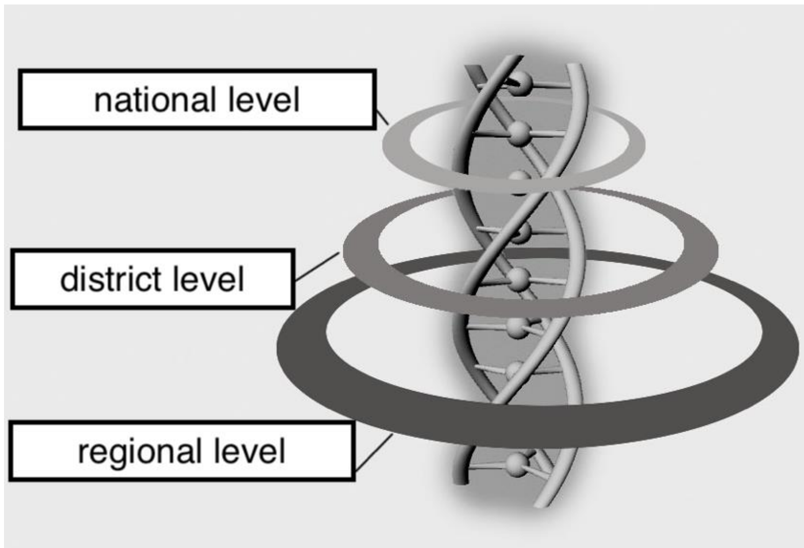


Figure 2.7. Model of interaction between the actors of the innovation process

Such a model of interaction between universities, business structures and the state, based on the integration function of higher schools, is able to bring the economy to a new level of development, increasing the efficiency and effectiveness of all forms of joint cooperation.

2.4. Evaluation of the effectiveness of the implementation of the mechanism of interaction of engineering and economic university science with participants in innovative activities

The collection of data on innovation activity indicators was carried out using various open sources of information from the official website of the university - http://spbstu.ru and reports on innovation activity of IPNT (Institute of Physics, Nanotechnology, and Telecommunications), Peter the Great St. Petersburg Polytechnic University.

A group of 4 experts from different fields of activity at the Peter the Great Polytechnic University (educational, research) and 3 experts from business sector were selected and surveyed twice. The first online survey was intended to indicate the weight of innovation activity indicators reflecting the significance of these indicators in the framework of innovation development (Appendix A). In the second online survey experts defined the forecast indicators of university's innovation activity after implementation of the proposed interaction mechanism (Appendix B). The surveys were conducted in March 2020.

Variables

Since the developed forms and mechanisms were aimed at solving the problem of the low level of commercialization of innovations in the university, in order to evaluate the effectiveness of the implemented measures, it is necessary to analyze the research activities reflecting the effectiveness of the ongoing research and development. We used indicators that characterize the structure of the university's income from research, publication, and patent activity according to ITMO monitoring of universities' innovation activity in Russia [103]. Thus, we distinguished four groups of indicators: 1) publication activity (the number of publications per scholar, citation of scientific works in scient metric databases (Web of Science / Scopus, RSCI)), 2) interaction with external participants (number of laboratories created by third-party organizations based on the university (participation in clusters), the share of R&D financing under contracts with business entities in the total volume of R&D), 3) grant activity (the number of applications for tenders; the amount of R&D financing by grants), 4) intellectual property (the number of created RIA with legal protection; the number of patents in collaboration with companies). The system of indicators for calculating the effectiveness of the implemented forms and mechanisms of interaction is presented in the Table. 2.3..

Table 2.3. The system of indicators for calculating the interaction effectiveness of innovation process participants.

Kind of activity (i)	Number of indicator. (j)	Name of indicator	Symbol. (Xij)
Publication activity	1	The number of publications per scholar (Russian base)	X_{11}
	2	The number of publications per scholar (WoS)	X_{12}
	3	The number of publications per scholar (Scopus))	X_{13}
	4	The number of publications' citations (Russian base) per scholar	X_{14}
	5	The number of publications' citations (WoS) per scholar	X_{15}
	6	The number of publications' citations (Scopus) per scholar	X_{16}
Integral indicator of publication activity			R_1
Interaction with external participants	1	The number of laboratories created by third-party organizations based on the university (participation in clusters)	X_{21}
	2	The share of R&D financing under contracts with business entities in the total volume of R&D	X_{22}
Integral indicator of interaction with external participants			R_2
Grant activity	1	The number of applications for federal grants	X_{31}
	2	The amount of financing of R&D by grants per scholar (thousand rubles)	X_{32}
Integral indicator of grant activity			R_3
Intellectual property	1	The number of RIA created with legal protection	X_{41}
	2	The number of patents in collaboration with companies	X_{42}
Integral Intellectual Property Indicator			R_4

3.3. Methodology on university's innovation activity evaluation

At the first stage, it is necessary to bring the system of indicators into a comparable form in order to ensure the possibility of calculating the integral indicator of evaluating the results of the innovative activities of the university. For this, it is proposed to carry out the procedure of standardizing indicators.

The procedure for normalizing each X_{ij} indicator will be carried out by calculating its actual value relative to the standard value adopted at the university. Reference values can be contained in the development strategy of the university (roadmap) and change as a result of changes in the target values of indicators. In the absence of target indicators in strategic plans, the maximum value of the indicator for a number of years can be chosen as the basis. Rationing of an indicator is carried out according to the formula 1.

$$r_{ij} = \frac{X_{ij}}{a} \times 100\%, \qquad (1)$$

r_{ij}– the normalized value of the indicator X_{ij}, is in the range from zero to one;

X_{ij}- the value of the j-th indicator for the i-th type of activity;

a – reference value of an indicator X_{ij}.

In the second stage, it is necessary to determine the weight coefficient, which reflects the significance of various indicators by types of innovation in the general system of indicators. For this, it is proposed to use the method of expert assessments (the first survey).

The need to calculate the integral relative indicator for each type of innovative activity (R_i) is due to the fact that in order to assess the level of interaction between the structural units of the university and innovative actors, there is a need to determine the weighting coefficients of indicators reflecting the significance of each of them by type of innovative activity. It is also proposed to do this on the basis of using the method of expert assessments, which allows determining the weight value of each i-th type of innovative activity in its total volume (K_i). The value K_i is formed on the basis of the summation of the values k_{ij} obtained during the same expert survey.

To participate in this survey, experts are selected from among the representatives of management involved in the management of innovative processes of higher education, representatives of the scientific community, and the teaching staff.

For each indicator X_{ij}, the expert sets the weight value of the j-th indicator for the i-th activity.

$$\sum_{m=1}^{M} k_{ij} = 1, \qquad (2)$$

k_{ij}– weight coefficient of the significance of the j-th indicator for the i-th type of innovation;

M – number of indicators in the system used.

Based on the previously obtained values of $r_{ij}$and expert estimates k_{ij},the integral relative indicator for each type of innovative activity (R_{iY}) is calculated in accordance with formula 3.

$$R_{iY} = \sum_{l=1}^{L} r_{ij} \times k_{ij}, \qquad (3)$$

R_{iY} – integral relative indicator for each type of innovation;

l =1, 2, …, L – the number of indicators for the i-th type of innovation.

It is proposed to solve the problem of the presence of different values of expert assessments of significance for X_{ij} indicators by calculating the weighted average value when the conditions for the consistency of expert opinions identified as a result of calculating Kendall’s concordance coefficient are satisfied. When calculating the level of integration of the University in the NIS, this indicator is used due to the presence of attributes of factors and the need to use an expert method to evaluate them. The value of this indicator above 0.4 indicates a fairly high consistency of opinions and the possibility of using the survey results to calculate the weighted average. For a higher reliability of results the minimum of 4 experts are needed to test for consistency of expert opinions.

The calculation of Kendall’s concordance coefficient is carried out by building the elements of the population from the most to the least important indicator. After ranking *n* elements (indicators), we get *m* sequence of ranks (number of experts).

$$\text{CON} = \frac{12S}{e^2(n^3 - n)}, \qquad (4)$$

CON – Kendall’s concordance coefficient, CON∈[0;1];

e – number of experts in the group;

n – number of indicators;

S – the sum of squares of rank differences (deviations from the mean).

Based on the system of indicators, it will be possible to construct a matrix of multicriteria assessment of the level of effectiveness of interaction (Table 2.4).

Table 2.4. Matrix of multicriteria assessment of the level of interaction effectiveness.

Name of indicator	Years 2019	2020	… №Y	Coef. significance
Block 1. Publication activity				
1. The number of publications per scholar (Russian citation base)	r_{111}	r_{211}	… r_{Y11}	k_{11}
2. The number of publications per scholar (WoS)	r_{112}	r_{212}	… r_{Y12}	k_{12}
3.The number of publications per scholar (Scopus)	r_{113}	r_{213}	… r_{Y13}	k_{13}
4. The number of publications' citations (Russian base) per scholar	r_{114}	r_{214}	… r_{Y14}	k_{14}
5. The number of publications' citations (WoS) per scholar	r_{115}	r_{215}	… r_{Y15}	k_{15}
6. The number of publications' citations (Scopus) per scholar	r_{116}	r_{216}	… r_{Y16}	k_{16}
Integral relative measure of publication activity	$\mathbf{R_{11}}$	$\mathbf{R_{12}}$	… $\mathbf{R_{1Y}}$	K_1
Block 2. Interaction with external participants				
1. The number of laboratories created by third-party organizations based on the university (participation in clusters)	R_{121}	r_{221}	… r_{Y21}	k_{21}
2. The share of R&D financing under contracts with business entities in the total volume of R&D	R_{122}	r_{222}	… r_{Y22}	k_{22}
Integral relative indicator for interaction with external actors	$\mathbf{R_{21}}$	$\mathbf{R_{22}}$	… $\mathbf{R2_{Y}}$	K_2
Block 3. Grant activity				
Amount of funds attracted for R&D / Total number of scholars * 100	R_{131}	R_{231}	… r_{Y31}	k_{31}
The number of RIAs created with legal protection / Total number of scholars * 100	R_{132}	R_{232}	… r_{Y32}	k_{32}
Integral relative indicator for grant activities	$\mathbf{R_{31}}$	$\mathbf{R_{32}}$	… $\mathbf{R_{3Y}}$	K_3
Block 4. Intellectual property				
The number of RIA created with legal protection	r_{141}	r_{24}	… r_{Y41}	k_{41}
The number of patents in collaboration with companies	$\mathbf{r_{142}}$	$\mathbf{r_{242}}$	… $\mathbf{r_{Y42}}$	K_{42}
Intellectual property integral relative Ratio	$\mathbf{R_{31}}$	$\mathbf{R_{32}}$	… $\mathbf{R_{3Y}}$	K_4

In table 2, the following notation is used:

k_{ijU}– the relative value of the j-th indicator for the i-th type of innovation in the Y-year;

K_{iU}– integral relative indicator for the i-th type of innovation in the Y-year;

P_{i} – coefficient of the significance of the integral relative indicator for the i-th type of innovation;

F_Y– assessment of the effectiveness of the university's interaction with innovative actors in the Y-year.

A comprehensive measure of the interaction efficiency $F_Y$is the sum of the relative dimensionless estimates of the indicators R_{iY}, which are determined by formula 3 (formula 5).

$$\mathrm{F_Y} = \sum_{\mathrm{l=1}}^{\mathrm{L}} \mathrm{R_{iY}}, \qquad (5)$$

i – index group number, i = 1,2,3…, n;

Y – year of assessment.

Using this indicator, we can determine the indicator of the interaction of all structural departments of the university with the actors of the innovation process as well as the effectiveness of innovation activity at university.

As the mechanism was introduced during the study, we propose to calculate the effectiveness of the implemented interaction mechanism on the basis of forecast estimates of indicators.

Below is a predictive assessment of the performance of SPbPU research activities taking into account the mechanisms for developing interaction proposed. The predictive assessment was carried out by the method of extrapolation of retrospective data for five years (scenario A) and the expert method (scenario B). The forecast indicators in Scenario B shows indicators taking into account the implementation of the proposed forms and mechanisms of interaction based on the constant cooperation of employees both within the university and with external participants (the second survey results).

Table 2.5. Scorecard for evaluating the effectiveness of introducing a new interaction mechanism.

№	Indicators	Scenario	2018 actual	2019 actual	2020 forecast	2021 forecast
			Publication activity			
1.	The number of publications per scholar (Russian base)	A	10,0	10,5	10,71	10,98
		B			11,5	12,5
2.	The number of publications per scholar (WoS)	A	1,9	2,5	2,82	3,22
		B			3,1	3,7
3.	The number of publications per scholar (Scopus)	A	3,1	4	4,67	5,4
		B			5,2	6,5
4.	The number of publications' citations (Russian base) per scholar	A	12,4	14,2	15,31	16,7
		B			15,5	16,8
5.	The number of publications' citations (WoS) per scholar	A	4,5	6,7	6,78	7,6
		B			7	7,9
6.	The number of publications' citations (Scopus) per scholar	A	6,2	9,5	9,94	11,5
		B			10,8	12
			Interaction with external participants			
7.	The number of laboratories created by third-party organizations based on the university (participation in clusters)	A	0	0	0,7	0,8
		B			1	2
8.	The share of R&D financing under contracts with business entities in the total volume of R&D	A	28,3	28,8	29,276	29,98
		B			32	35
			Grant activity			
9.	The number of applications for federal grants	A	48	70	69,9	78
		B			70	80

10.	The amount of R&D financing by grants in one research and development work (thousand rubles)	A	25,7	28,8	31,137	33,86
		B			30,1	34,2
			Intellectual property			
11.	The number of RIA created with legal protection	A	10	14	14,4	16,2
		B			16	20
12.	The number of patents in collaboration with companies	A	0	0	0	0
		B			1	2

Notes: * A - indicators excluding the implementation of the mechanism; ** B - after the introduction of the mechanism of continuous cooperation between structural units of the university among themselves and with participants in innovative activities.

To calculate the effectiveness of the interaction between structural units with each other and with external participants in innovation, we propose using forecast indicators for 2021 according to scenarios A and B.

The effectiveness of the implemented forms and mechanisms of interaction will be calculated according to formula 6.

$$W = F_B - F_A , \qquad (6)$$

F_B – effectiveness of interaction without taking into account the implementation of measures;

F_A – the effectiveness of the interaction after the introduction of the mechanism of continuous cooperation.

4. Results

The results of calculating the concordance showed that the consistency of experts' opinions is quite high, the coefficient was 0.6, which indicates the presence of similar opinions regarding the influence of one factor or another on the level of effectiveness of the university's interaction with participants in the innovation process, as well as on the forcing of a single image of the future university.

Based on the results of the first survey, the calculation of the consistency of experts' opinions in the areas of publication activity, interaction with external participants, competitive activity, intellectual property made it possible to distribute weight coefficients according to indicators included in a comprehensive indicator of the level of effectiveness of the interaction of internal and external innovative interaction (table 2.6).

Table 2.6. The results of an expert survey and the calculation of weighted indicators for assessing the effectiveness of interaction.

Indicator / Expert	Expert 1.1.	Expert 1.2.	Expert 2.1.	Expert 2.2.	Expert 3.1.	Expert 3.2.	Expert 3.3.	Coefficient of significance, k_i
K_1				**Publication activity**				**0, 24**
X_{11}	0,024	0,027	0,03	0,022	0,025	0,028	0,025	0,026
X_{12}	0,05	0,049	0,047	0,055	0,045	0,047	0,052	0,049
X_{13}	0,061	0,056	0,055	0,064	0,058	0,055	0,059	0,058
X_{14}	0,018	0,025	0,027	0,02	0,024	0,026	0,023	0,023
X_{15}	0,041	0,04	0,038	0,047	0,04	0,035	0,039	0,04

X_{16}	0,047	0,044	0,042	0,047	0,041	0,044	0,046	0,044
K_2				**Interaction with external participants**				**0,3**
X_{21}	0,09	0,12	0,11	0,13	0,1	0,12	0,1	0,11
X_{22}	0,21	0,19	0,2	0,2	0,17	0,21	0,19	0,19
K_3				**Grant activity**				**0,15**
X_{31}	0,062	0,05	0,064	0,068	0,063	0,057	0,059	0,06
X_{32}	0,079	0,093	0,09	0,088	0,095	0,093	0,094	0,09
K_4				**Intellectual property**				**0,31**
X_{41}	0,16	0,19	0,15	0,13	0,16	0,19	0,16	0,16
X_{42}	0,14	0,13	0,17	0,16	0,15	0,18	0,14	0,15

We summarize the data obtained from the system of indicators for assessing the effectiveness of interaction in table 2.7.

Table 2.7. Interaction Performance Indicators.

Interaction Level Indicators	2021 (Scenario A)	2021 (Scenario B)
	Publication activity	
X_{11}	***10,98***	**12,5**
X_{12}	***3,22***	**3,7**
X_{13}	***5,4***	**6,5**
X_{14}	***16,7***	**16,8**
X_{15}	***7,6***	**7,9**
X_{16}	***11,5***	**12**
	Interaction with external participants	
X_{21}	***0,8***	**2**
X_{22}	***29,98***	**35**
	Grant activity	
X_{31}	***78***	**80**
X_{32}	***33,86***	**34,2**
	Intellectual property	
X_{41}	***16,2***	**20**
X_{42}	***0***	**2**

Based on the sum of the products of normalized values and weighted values of the indicators, we calculate the integral indicator and indicators for innovation groups. We summarize the data in table 2.8.

Table 2.8. Indicators for assessing the level of interaction effectiveness after normalization.

Interaction Level Indicators, r_i	2021 (Scenario A)	2021 (Scenario B)
	Publication activity	
r_{11}	95,47	108,69
r_{12}	92,00	105,71
r_{13}	94,73	114,03
r_{14}	101,21	101,81
r_{15}	100,00	103,95
r_{16}	100,00	104,35
R_1	23,21	25,71
	Interaction with external participants	
r_{21}	80,00	200,00
r_{22}	93,17	117,6
R_2	26,5	44,34
	Grant activity	
r_{31}	111,43	114,28
r_{32}	112,86	114,00
R_3	16,84	17,12
	Intellectual property	
r_{41}	98,18	121,21
r_{42}	0,00	200,00
R_4	15,7	49,39
$\mathbf{F_Y}$	**82,25**	**136,56**

Based on the calculation results, the values of the interaction level of university structures among themselves and with participants in the innovative activity, as well as the effectiveness of the implemented forms and mechanisms of interaction, are obtained (table 2.9).

Table 2.9. Indices of the interaction effectiveness level and the effectiveness of the implemented forms and mechanisms of interaction.

	$\mathbf{R_1}$	$\mathbf{R_2}$	$\mathbf{R_3}$	$\mathbf{R_4}$	**Index Value $\mathbf{F_Y}$**	**Index Value W**
Scenario A 2021	23,21	26,5	16,84	15,7	82,25	**56,31**
Scenario B 2021	25,71	44,34	17,12	49,39	136,56	

According to the obtained values, the implementation of the developed interaction mechanism will have a positive effect on the effectiveness of interaction both within the university and with external participants in the innovation process. The indicator of the interaction effectiveness of scenario A forecast values is lower than the indicator of the interaction effectiveness of the scenario B forecast values by 39.77%, which indicates a significant impact of the implemented mechanism on the effectiveness of the interaction. Thus, our hypothesis was confirmed.

From the Enlightenment, when the norms and practices of open science were formulated, to this day, openness in science has continued to evolve in accordance with the economic, political, sociocultural, and technological constructs of each period. The work of many scientists [50,51,52] contributed to the correct perception of a new scientific space, including the ways of interaction of scientific agents to create effective communication aimed at achieving the research objectives. It is important to note that the principles of open science and innovation allow modern universities to increase the share of commercialized projects, as well as promote the scientific community outside the walls of universities, reaching new levels. Based on the studied works, our case at the Peter the Great Polytechnic University showed positive correlation between level of university interaction with other innovation system actors and the general level of university’s innovation activity indicators.

We developed and proposed mechanism for the university’s interaction with other actors of the innovation system based on the online platform for open innovation, which allows to increase the effectiveness of joint scientific, and innovative activities. Although policy, debate and action at the national, regional and global levels regarding openness in science seems to still revolve around the "sharing of scientific results" through open data and open access, there has already been a significant shift in the mindset of researchers towards greater openness in science throughout the research cycle by university research groups. In our study, we proposed a mechanism for ensuring the openness of science, not only in the research process. Within the framework of the proposed mechanism, the possibility of creating project groups, analyzing topical research topics has been implemented, and functionality has also been developed for business partners, which allows companies to navigate among the variety of innovations and invest in projects that they demanded.

The creation of such a mechanism was based on the concepts of open science and open innovation. Having studied these concepts and their contribution to the development of science, it was possible to implement the Living Labs in the university environment. The openness of science contributed to the expansion of contacts among researchers, simplified the search for potential collaborators with similar scientific interests, opened access to the study of previous research and expanded the horizons for new scientific discoveries. In turn, the openness of innovations gave impetus to the promotion of scientific projects developed within the framework of open science. Thus, Living Labs are implemented for the development of open science and open innovation within the university. This is reflected in the results of our study, since the data we process shows an increase in publication activity, interest in grant competitions and an increase in the university's interaction with other members of the scientific community.

Based on the proposed by the university of ITMO methodology on innovation activity monitoring, we carried out a comprehensive multi-criteria analysis of interaction mechanism effectiveness. The calculation was carried out on the basis of forecast estimates made by extrapolation of retrospective data for five years (scenario A) and by an expert method (scenario B). As a result, we revealed that the proposed interaction mechanism should contribute to the increment of innovative indicators of the university and, as a consequence, the development of an innovative economy. Thus, our hypothesis about the positive influence of the proposed mechanism on the interaction between innovation system actors and increase the effectiveness of innovation activity of university was confirmed.

The indicator of the level of effectiveness of interaction in a broad sense reflects the level of demand for goods and services created by the university using the latest achievements of science and technology from the participants of the external environment. This indicator is an important indicator of the effectiveness of the three types of innovative activities of the university and its calculation will allow to control the success in each of these areas, in particular the effectiveness of commercialization.

3. CONCLUSION

As a result of the study, the authors obtained the following theoretical and methodological conclusions and formulated practical recommendations:

1. It is revealed that the formation of an innovative economy is conditioned by a high level of interaction between universities and business structures. Thus, on the basis of the analysis, the reason for the innovative stagnation of Russia was revealed, namely, the insufficient integration of technologically advanced companies at the regional level, associated with incomplete interaction between the academic and business environment. This phenomenon is explained by the underestimation of the factor of involvement of university science on the part of high-tech companies. A scheme of institutional conditions for an effective integration process is proposed. Systemic defects in the

construction of the innovation infrastructure in Russia have been revealed, which consist mainly in the underdevelopment of relations between the key participants in innovation activity. The conceptual foundations of the interaction of subjects have been developed through the implementation of the integration function of the university.

2. New forms and mechanisms of effective interaction of the university with business structures and the state on a network basis are proposed, contributing to effective cooperation between the internal departments of the university, as well as enhancing innovation with participants in the national innovation system. As open platforms for innovation, it was proposed to introduce the "Living laboratory", focused on interaction and cooperation in the process of implementing innovative activities of the internal departments of the university, and the "Network business incubator", on the basis of which it is supposed to effectively promote the created innovations among business structures, search for funding opportunities and accumulate ideas together with the business to implement future research and development. Also, an organizational model was developed for the Coordination Center for the Promotion of Innovations on the basis of the economic division of the university, which will directly contribute to the implementation of the proposed interaction mechanisms. The main function of this center will be the development of integration processes, both between the internal departments of the university and with external participants.

3. Developed and tested a methodology for a comprehensive multi-criteria assessment of the indicator of the effectiveness of the interaction of the university with the participants of the innovation system, which allows you to obtain a standardized indicator for a certain period, both for monitoring the development of innovative activities and making the necessary adjustments, and for determining the effectiveness of already implemented measures. To calculate the effectiveness of the implementation of the proposed forms and mechanisms for integrating university science into the national innovation system, we used indicators of predictive estimates, both expert and calculated by extrapolation. According to the results obtained, the implementation of the developed forms and mechanisms of interaction will have a positive effect on the effectiveness of interaction both within the university and with external actors of the innovation process and can be recommended for implementation in multidisciplinary universities.

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Appendixes

Appendix A. Survey on forecast indicators of university's innovation activity

Dear participants!

The questionnaire is aimed at carrying out a predictive assessment of the indicators of the university's innovative activity after the introduction of an online platform of open innovations based on the "Living Laboratory" and "Networked Business Incubator".

It is necessary to analyze 12 indicators in 4 blocks. Please indicate the forecast indicators in accordance with your opinion in Table 1. Before answering, please read the data for 2015 -2019 (university innovation activity indicators):

Table 1.

№	Indicators	2020	2021
	Publication activity		
1.	The number of publications per scholar (Russian base)		
2.	The number of publications per scholar (WoS)		
3.	The number of publications per scholar (Scopus)		
4.	The number of publications' citations (Russian base) per scholar		
5.	The number of publications' citations (WoS) per scholar		
6.	The number of publications' citations (Scopus) per scholar		
	Interaction with external participants		
7.	The number of laboratories created by third-party organizations based on the university (participation in clusters)		
8.	The share of R&D financing under contracts with business entities in the total volume of R&D		
	Grant activity		
9.	The number of applications for federal grants		
10.	The amount of R&D financing by grants in one research and development work (thousand rubles)		
	Intellectual property		
11.	The number of RIA created with legal protection		
12.	The number of patents in collaboration with companies		

Appendix B. Survey on weight value of innovation activity's indicators

A survey of experts within the framework of the methodology for a comprehensive assessment of the effectiveness of the university structural divisions' interaction with actors of innovative activity

Expert opinion is intended to determine priorities between indicators of publication activity, interaction with external actors, competitive activity, and indicators of intellectual property, as well as between their constituent areas within each of the listed indicators. Therefore, you are offered a two-step completion of the tables below.

In the first stage, it is necessary to arrange the weights in Table 1. Each of the four blocks is assigned values from 0 to 100%, in accordance with the degree of influence exerted by each block on the resulting indicator (interaction with innovation actors).

Table 1. Composition of the indicator of the effectiveness of the structural units' interaction with each other and with innovative actors in the field of innovation.

Indicator	Type of innovation activity	Weight value,%
Effectiveness of university interaction with innovative actors	Publication activity	
	Interaction with external actors	
	Grant activity	
	Intellectual property	
	Total	100

At the second stage, for each of the types of innovation activity, it is necessary to arrange the weights for a number of indicators detailing the elements of innovation in each of the blocks. The total sum of the entered values within one type of activity must also be 100%.

The first block is "publication activity" (table 2).

Table 2. The composition of the block of publication activity indicators.

Indicator	Areas of work being implemented	Weight value, %
Publication activity	The number of publications per scholar (Russian base)	
	The number of publications per scholar (WoS)	
	The number of publications per scholar (Scopus)	
	The number of publications' citations (Russian base) per scholar	
	The number of publications' citations (WoS) per scholar	
	The number of publications' citations (Scopus) per scholar	
	Total	100

The second block is "interaction with external actors" (table 3).

Table 3. Composition of the block of indicators of interaction with external actors.

Indicator	Type of innovation activity	Weight value,%
	The number of laboratories created by third-party	

Interaction with external actors	organizations based on the university (participation in clusters)	
	The share of R&D financing under contracts with business entities in the total volume of R&D	
	Total	100

The third block is grant activity (table 4).

Table 4. Composition of the block of indicators of grant activity.

Indicator	Type of innovation activity	Weight value,%
Grant activity	The number of applications for federal grants	
	The amount of R&D financing by grants in one research and development work (thousand rubles)	
	Total	100

The fourth block is intellectual property (table 5).

Table 5. The composition of the block of intellectual property.

	Areas of work being implemented	Weight value, %
Intellectual property	The number of RIA created with legal protection	
	The number of patents in collaboration with companies	
	Total	100

Additionally: What sphere of experts do you consider yourself to be most? (Underline whatever applicable)

(1) Education

(2) Science

(3) Entrepreneurship

(4) other: _____________________