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THREE-LEVEL MODEL OF THE NATIONAL INNOVATION SYSTEM OF UKRAINE



Introduction. For National Innovation Systems (NIS) playing an important role in building the modern economies, the development and improvement of the NIS model of Ukraine is an urgent task.

Problem Statement. There are many models of NIS in the world but they cannot be used by Ukraine, since they do not take into account the specifics of its socioeconomic development.

Purpose. To develop a model for the NIS of Ukraine containing a necessary and sufficient set of subsystems, elements, and links between them and taking into account the specific features of the socioeconomic development of Ukraine.

Materials and methods. The scholarly research publications of domestic and foreign researchers, legal acts, methods of analysis and synthesis have been used in the work.

Results. Based on system approach, a comprehensive NIS model has been obtained. It covers the four stages of the innovation process and considers the impact of national and international innovation community on them.

Conclusions. A three-level model of the NIS of Ukraine has been proposed. It has necessary and sufficient number of elements and connections between them for the implementation of the NIS functions. The model can be used as a tool for preparing strategic decisions to optimize the NIS of Ukraine.

Keywords: national innovation system, innovation process, infrastructure, and model.

The development of knowledge-based economy in Ukraine implies creating conditions for the transformation of R&D potential into a key resource for sustainable economic growth [1]. The essence of innovation activity is the maximization of socioeconomic effect by raising efficiency of the use of intellectual labor (intellectual capital). A universal tool for transforming the results of intellectual work into innovative products or innovative services is National Innovation System (NIS). Therefore, the development of NIS models and their improvement are an urgent task for each country.

There are many definitions of the NIS in the literature [2], in particular, «The national inno-

vation system is a set of interlinked organizations (structures) engaged in the production and commercialization of scientific knowledge and technologies within national boundaries» [2, 22]. The common thing for NIS is that they form such a system of relationships between science, industry, and society, in which economic development is based on innovation.

In works [3–6], several dozen NIS models have been analyzed for both advanced economies and developing countries, in particular, for Ukraine. This analysis shows that the systems differ in the number of elements, the presence or absence of links between the elements, the strength of the links, and the openness or closeness to the international innovation environment. There is no holistic view of NIS, its elements and their interaction [2].

In our opinion, the existence of so many different NIS models is explained by, at least, two reasons: firstly, by different levels of socioeconomic development of the countries, and secondly, by the lack of consistent understanding of the system concept.

The official definition of the NIS of Ukraine is given in the Concept of the National Innovation System development [7], «The national innovation system is a set of legislative, structural, and functional components (institutions) involved in the process of creating and applying scientific knowledge and technologies and defining legal, economic, organizational, and social conditions to assure the innovation process». This document also specifies that the National Innovation System includes the following subsystems: state regulation, education, knowledge generation, innovation infrastructure, and production.

This definition cannot be a reliable basis for the development of the NIS model of Ukraine, since it does not include such subsystems as the implementation of innovative products, as well as an innovation environment. At the same time, the subsystem «education» is unnecessary, because it is a separate self-sufficient system. There are no links between the subsystems, and the system features related to Ukraine's transition from a planned to a market economy are neglected.

A mere replication of the best foreign NIS models, even the triple helix model by H. Etzkowitz and L. Leydesdorff [8, 9], is a wrong way for Ukraine, insofar as the mentioned models are designed for the countries with high level of socioeconomic development. Therefore, it is necessary to develop NIS models which take into consideration all specific features of Ukraine, including, the historical aspects.

The purpose of this research is to develop a model of the NIS of Ukraine, which contains the necessary set of subsystems and their elements sufficient for its proper operation, establishes the links between them, and takes into account the peculiarities of the transition of Ukraine from the planned to the market model of economic devel-

opment. The research is based on monographs, scholarly research articles, reports, dissertations of domestic and foreign researchers, legal acts and regulations, and results of scientific discussions. The author has used methods of analysis, synthesis, and systematic approach principles.

Comprehensive approach to NIS model formation. «System» is the key word in the «national innovation system» collocation. There are, at least, several dozen definitions of the term «system», however, no single generally accepted interpretation of it has been given [10]. In [11] there is a definition «System is complete holistic set of elements (components) linked to each other and interacting in such a way as to realize the system function».

The elements of system are objects and subjects of innovation activity and links between them. The links are elements that realize a direct interaction between the elements (or subsystems) of the system and the elements and subsystems of the environment [11].

Having analyzed the numerous definitions of «system» one can determine the properties commonly found in the system:

- ✦ The system is the whole of subsystems (elements);
- ✦ Both subjects and objects of innovation activity as well as links between them can be the system elements;
- ✦ The links between the elements must be stronger than those between them and the elements of environment;
- ✦ The system elements must be linked to each other in such a way as to assure the system function.

It should be noted that the system can be an element of other higher order system (supersystem) and/or include lower-order systems (subsystems). Hence, «element», «subsystem», «system», and «supersystem» are interconverted concepts.

Principal model of the NIS of Ukraine. Proceeding from the above mentioned concepts and properties of the system and having considered

the results of innovation process studies [12, 13], a NIS model that consists of the three interrelated subsystems has been developed (Fig. 1):

- ✦ Innovation process subsystem (IPS);
- ✦ Subsystem of government support to innovation activity (SGSIA);
- ✦ subsystem of international relations in the field of innovation (SIRFI).

These subsystems are linked to each other in such a way as the SGSIA is a system with respect to the IPS, with SIRFI being a supersystem with respect to SGSIA.

The subsystems are related to each other with both direct and inverse links. The SIRFI is linked to the IPS mainly via SGSIA. Let us consider models of each subsystem separately.

Innovation process subsystem (IPS) model.

If the manufacture of innovation products is a process starting with inventions or other intangible results of intellectual labor and ending with a profit-generating innovation (innovation products, innovation services, and innovation works) [12], it is advisable to consider its stages as elements of innovation process subsystem. Joseph Schumpeter [12] distinguished the three stages: research, development, and diffusion. H. Carpenter counted the six stages, including formulation of purposes of innovation and realization of ideas [13]. There are models with more stages [14].

Historically, since the time of planned economy, Ukraine, like many post-Soviet countries, has got an innovation process model consisting of the four stages: research, R&D and design works, manufacture, and supply [15]. While transiting to the market economy, only the supply stage has undergone a significant transformation. This stage that was typical for the planned economy, under the market economy conditions, has transformed into commercialization. The research stage has remained almost unchanged. At the R&D and design works stage, the number of R&D and design institutes has decreased essentially, but their infrastructure has not altered radically. At the manufacture stage, many industrial corporations have been privatized, but their infrastruc-

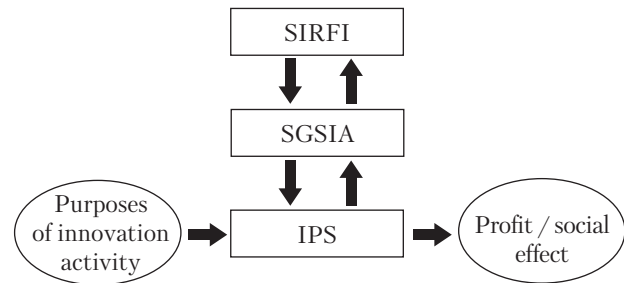


Fig. 1. Triple-level model of the national innovation system of Ukraine: – Innovation process subsystem (IPS); – Subsystem of government support to innovation activity (SGSIA); – subsystem of international relations in the field of innovation (SIRFI)

ture has not changed much. Thus, the innovation process stages were formed as far as in the Soviet time, except for the commercialization one, and have remained almost unchanged.

Let us reproduce the innovation process subsystem model considering the mentioned above concepts and properties of the system, as well as the history of Ukraine’s economy, in the following way (Fig. 2).

Fig. 2 shows the model «from idea to commercialization of innovation products in the market» belonging to Schumpeter’s linear model [12] that recently has been compared with the nonlinear (interactive) model considering both direct and inverse links between the model elements [14]. Naturally, the latter is often applied in the case of specific innovation, when a new idea that appears even at the last stage of innovation process can be a trigger for the first stage (Fig. 2). However, as for the national innovation system that generalizes a lot of innovations, the integral linear model (Fig. 2) is more suitable. The ultimate outcome of this subsystem is economic benefit (for instance, profit) from sales of innovation products, services or works or other (social) benefit.

The first stage of innovation process is survey works, fundamental and applied research. The fundamental research aims at getting new knowledge or understanding of fundamental aspects (facts and phenomena), which are not directly related to the development of specific product or

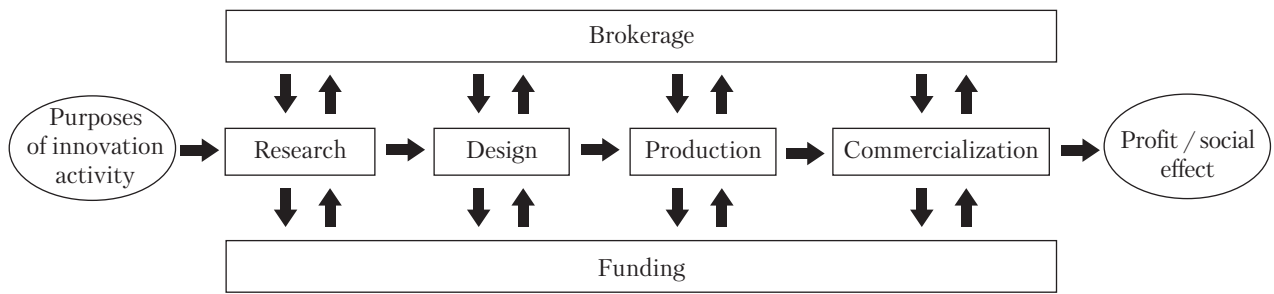


Fig. 2. Innovation process subsystem model

technology. The surveying R&D works are the works aiming at expanding knowledge to deeper understand the studied subject, to forecast science and engineering development, and to study how to use the discovered phenomena and regularities. The applied R&D works are the works to address specific scientific problems for creating new products and technologies [15]. Mainly at this stage, the intellectual property securing the competitive ability of products is created.

At the second stage, new products and technologies are designed. The main outcomes of these works are design documents and specifications, manufacture and testing of samples.

At the third stage, the manufacture of innovation products is prepared and mastered. In broad sense, the innovation products are goods, services or works based on outcomes of intellectual or creative labor.

The main objective of the fourth stage is to obtain an extra (innovation) profit or other (social) benefit from sales of innovation products.

Infrastructure is an important component of the innovation process subsystem, insofar as it helps realizing the processes of each subsystem element. According to the model, the processes at each stage (element) are primary, while the infrastructure is secondary. The infrastructure is not generalized for the whole subsystem, it is considered separately for each subsystem element.

The «research» element infrastructure is based on R&D institutions and organizations of all types of ownership, in particular, R&D institutes of the national and industrial academies of sciences,

universities, and industrial R&D institutes, etc. This infrastructure is inherited from Soviet Union almost unchanged. Concentration of R&D in the government sector at a low innovation activity of the industrial sector is typical for Ukraine, like for other post-Soviet countries, in particular, Russia [22]. In addition, the post-Soviet innovation systems have regressed as a result of broken system elements, and, consequently, reduction in the system capacity as a whole [23].

The analysis of foreign experience has shown that the NIS definitely meets socioeconomic relations and production capacity of the country, i.e. the NIS must be formed individually for each country [22].

The «design» element infrastructure includes industrial R&D and design institutes, pilot factories of the national and industrial academies of sciences, design offices, technological clusters, science parks, technology parks, business incubators, engineering firms, etc.

The «production» element infrastructure mainly consists of organizations and corporations of government, municipal, and private ownership, which manufacture innovation products or provide innovation services or works.

The «commercialization» element infrastructure is sellers and buyers of innovations, as well as market entities, both individuals, and corporates. It should be noted that the innovation market has three segments: the intellectual property market, the innovation project market, and the market of innovation products (ready-to-use goods and services). Therefore, depending on the mar-

ket segment, its infrastructure varies. For example, the subjects of all three preceding elements of the subsystem can act both as seller and as buyers of innovations.

To ensure the integrity of the subsystem the links between its elements must be taken into consideration. As experience shows, the links are a weak point of the NIS of Ukraine. This is explained by the fact that different stages are realized by different groups of people: scholars, developers, manufacturers, and market experts. These groups have weak relations between each other and often do not understand each other. Therefore, one more group, the innovation or technology brokers, is required. They have a holistic understanding of innovation process and are capable of establishing links among all elements of the subsystem. They create one more element of the subsystem, the «brokerage» (Fig. 2).

«Funding» is an important element of the innovation process subsystem. The subsystem as a whole cannot perform its function unless the processes and infrastructure of each its stage are properly funded. It should be noted that funding can be realized not only as direct financing but also as economic aid, tax relief or other privileges. In Ukraine, the «research» stage is funded mainly from the consolidated budget. However, the government cannot fund the second and the third stages of innovation process subsystem, since, according to expert data, «research» to «design» to «manufacture» funding ratio is 1:10:100. Hence, to fund the second and the third stages it is necessary to attract investors. The creation of the National Research Fund has been foreseen by the Law of Ukraine on Science and R&D Activities for partial funding of innovation projects at the initial stage [16].

Model of the subsystem of government support to innovation activity (SGSIA). The innovation process subsystem is self-sufficient since it is able to realize the innovation process in full, from formulating the purpose of innovation activity to gaining an economic or social effect (Fig. 2). However, this subsystem operates under the in-

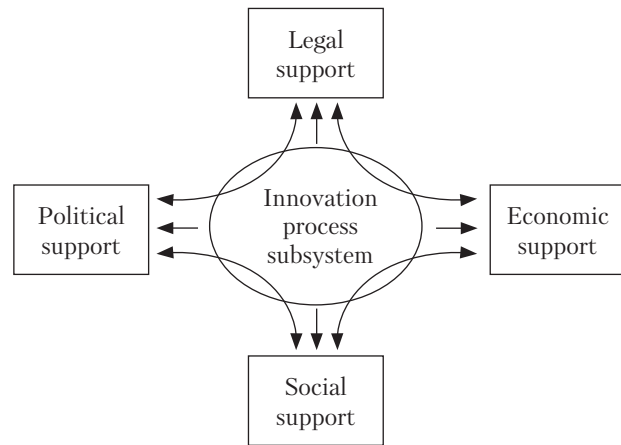


Fig. 3. Subsystem of government support to innovation activity

fluence of government and this influence can significantly modify the ultimate outcome (Fig. 1). The government influence, upon the results of expert surveys, is realized chiefly in the four ways: political, legal, economic, and social ones [17].

The main objective of SGSIA (Fig. 3) shall be to create favorable conditions for the operation of innovation process subsystem. This subsystem shall nourish the effective operation of IPS. Government attempts to interfere in the innovation activities management, moreover, in specific innovation projects are a wrong way. This is emphasized by R. Nelson [18] who objects to any stiff centralized government regulation and planning within the NIS framework.

The SGSIA consists of politics, legal, economic, and social institutions that establish and ensure compliance with regulations, rules, and requirements in the innovation field. Pursuant to the given NIS model (Fig. 1), the SGSIA includes the four elements: political, legal, economic, and social support (Fig. 3).

The subjects of «political support» element are the Administration of the President of Ukraine, Verkhovna Rada of Ukraine, Cabinet of Ministers of Ukraine, industrial ministries, political parties, NGOs, etc. The main objectives of this subsystem are to determine the strategy for innovation development of Ukraine and priority directions of

science and engineering development, as well as the strategy for Ukraine's transition to the innovation development model, adoption of government target programs, assignment of functions concerning the government support to innovation activities among central government bodies, etc.

The main subjects of «legal support» element are Verkhovna Rada of Ukraine, Ministry of Justice of Ukraine, parliament members and central government bodies and self-governing bodies, which have the right to legislative initiative. The main objective of this element is to create laws of Ukraine and bylaws regulating the legal relations between the entities involved in innovation activities. As of today, a rather large number of laws and bylaws in the field of innovation activity has been ratified [19]. However, there are many issues related to transfer of rights to intellectual property created at the expense of government funds, as well as the issues of public-private partnership in innovation activity, which have not been regulated by law. The implementation of the Law of Ukraine on Science and R&D Activities in terms of the creation and operation of the National Research Fund of Ukraine, etc. has not been completed [16]. This element of the NIS shall be systematically improved.

Usually, the government supports the innovation process both in monetary form and indirectly, by means of tax relief and other privileges. The government finances, mainly, the first stage of the innovation process, the scholarly research. The Law of Ukraine on Science and R&D Activities [16] establishes this funding at a rate of 1.7% of GDP. However, at parliament hearings [20], it was stated that funding of science and R&D activities from the national budget makes up only 0.27% of GDP that is much less than the critical amount (0.9%). The sustainable innovation development is impossible if the funding is under the minimum amount.

The science funding from the national budget shall be certainly added. However, even under such a miserable funding it is possible to raise its

efficiency, for instance, due to optimal reallocation among the objects to be financed, including by means of competitive funding. The other way to increase the financial support is to create favorable conditions for attracting domestic and foreign investors.

Tax relief for small innovative business, exemption from customs duties on scientific equipment and chemical reagents, facilitation of engagement of Ukrainian researchers in international R&D projects, etc. are additional resources for financial support of the innovation process.

The «social support» element is important, first of all, because it ensures a high level of social security for those who create new knowledge and intellectual property, which underlie any innovation. The social security of researchers, as per the Law of Ukraine on Science and R&D Activities [16], is important, but not sufficient means to raise a prestige of researcher job. The junior researcher salary is half the average wage in Ukraine [20]. Science and R&D activities are not popular in the society. As a result, every year the number of researchers engaged in science and R&D activities decreases [21].

The studies have shown that the SGSIA is characterized by structural deformation, institutional incompleteness, lack of coordination and misbalanced elements [2] and needs to be upgraded and finalized.

Model of the subsystem of international relations in the field of innovation (SIRFI). This model has the same structure as the SGSIA model. It has the same elements — political, legal, economic, and social ones. However, the mechanism of influence of this subsystem on the innovation process subsystem is different. It is realized, mainly, through the SGSIA, however, direct links between the SIRFI and IPS are possible as well.

Foreign partners in innovation activity are involved in all segments of R&D works in Ukraine. There are joint ventures, partnerships within the framework of contract-based research, and joint R&D projects. The number of western corporations that make contracts with Ukrainian R&D

institutes for carrying out commercial research. The Ukrainian research institutions make efforts to mobilize foreign support and to carry out contract-based research. Dozen American and European government and nongovernment funds and organizations provide support to noncommercial R&D activities in Ukraine. Ukrainian researchers receive grants and exchange staff and experience within the framework of European programs. These activities are regulated by international agreements and EU Directives in the field of innovation.

This subsystem is expected to have a favorable effect on the operation of the NIS of Ukraine as a whole. This assumption is based on signed EU-Ukraine Association Agreement and Ukraine's membership in EU *Horizon 2020* Program, etc.

The share of sold innovation products in the total industrial products sold in Ukraine makes up only 1.4% (as of 2015) [21]. This means Ukraine needs to use foreign-made innovation products. In the near future, the science sphere will

completely collapse as a result of its malfunctioning and functional capabilities of other elements of the innovation process subsystem of the NIS will substantially degrade with respective consequences for the economy as a whole, unless cardinal measures are taken.

Ukraine still has favorable preconditions (rather high level of research results, a large number of researchers, developed infrastructure of R&D institutions) for preventing a downshift to the innovation users [23] and for joining the innovators in the future.

The proposed triple-level model of the NIS of Ukraine, which has required and sufficient number of elements for its operation can be used as a convenient tool for preparing strategic decisions on optimization of the NIS of Ukraine. The model enables to comprehensively study the influence of specific subsystems, subsystem elements, strength of links between them, etc. on the ultimate outcome of the system functioning, namely, on achieving an economic or social effect.

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ТРИРІВНЕВА МОДЕЛЬ НАЦІОНАЛЬНОЇ ІННОВАЦІЙНОЇ СИСТЕМИ УКРАЇНИ

Вступ. Національні інноваційні системи (НІС) відіграють важливу роль у побудові сучасних економік, тому розробка й вдосконалення моделі НІС України є актуальним завданням.

Проблематика. У світі існує багато моделей НІС, однак вони не можуть бути використані Україною, оскільки не враховують особливостей її соціально-економічного розвитку.

Мета. Розробка моделі НІС України, що містить необхідний і достатній для виконання функцій НІС набір підсистем, елементів і зв'язків між ними, а також враховує особливості соціально-економічного розвитку України.

Матеріали й методи. В роботі використано огляд наукових публікацій вітчизняних і зарубіжних вчених, нормативно-правові акти, методи аналізу й синтезу.

Результати. На основі системного підходу отримано комплексну модель НІС, що включає чотири стадії інноваційного процесу, а також враховує вплив на них держави й міжнародного інноваційного співтовариства.

Висновки. Запропоновано трирівневу модель НІС України, яка має необхідну й достатню кількість елементів і зв'язків між ними для повноцінного функціонування НІС. Модель може бути використана як інструмент для підготовки стратегічних рішень оптимізації НІС України.

Ключові слова: національна інноваційна система, інноваційний процес, інфраструктура, модель.

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ТРЕХУРОВНЕВАЯ МОДЕЛЬ
НАЦИОНАЛЬНОЙ ИННОВАЦИОННОЙ СИСТЕМЫ УКРАИНЫ

Введение. Национальные инновационные системы (НИС) играют важную роль в построении современных экономик, поэтому разработка и совершенствование модели НИС Украины является актуальной задачей.

Проблематика. В мире существует много моделей НИС, однако они не могут быть использованы Украиной, поскольку не учитывают особенностей ее социально-экономического развития.

Цель. Разработка модели НИС Украины, содержащей необходимый и достаточный для выполнения функций НИС набор подсистем, элементов и связей между ними, а также учитывающей особенности социально-экономического развития Украины.

Материалы и методы. В работе использованы научные публикации отечественных и зарубежных ученых, нормативно-правовые акты, методы анализа и синтеза.

Результаты. На основе системного подхода получена комплексная модель НИС, включающая четыре стадии инновационного процесса, а также учитывающая воздействие на них государства и международного инновационного сообщества.

Выводы. Предложена трехуровневая модель НИС Украины, которая имеет необходимое и достаточное количество элементов и связей между ними для полноценного функционирования НИС. Модель может быть использована в качестве инструмента для подготовки стратегических решений по оптимизации НИС Украины.

Ключевые слова: национальная инновационная система, инновационный процесс, инфраструктура, модель.