

Електронний журнал «Ефективна економіка» включено до переліку наукових фахових видань України з питань економіки (Категорія «Б», Наказ Міністерства освіти і науки України № 975 від 11.07.2019). Спеціальності – 051, 071, 072, 073, 075, 076, 292. Ефективна економіка. 2022. № 6.

DOI: 10.32702/2307-2105.2022.6.5

УДК: 330.341

A. Rusnak,

*Doctor of Economic Sciences, Professor, Professor of the Department of Economics,
Kherson Educational-Scientific Institute of Admiral Makarov National University of
Shipbuilding, Mykolayiv, Ukraine*

ORCID ID: 0000-0002-3198-2866

D. Lomonosov,

*PhD in Economics, Associate Professor, Associate Professor of the Department of
Economics, Kherson Educational-Scientific Institute of the Admiral Makarov
National University of Shipbuilding, Mykolayiv, Ukraine*

ORCID ID: 0000-0003-4394-1807

FUNCTIONS, STRUCTURE AND INDICATORS OF NATIONAL INNOVATION SYSTEM PERFORMANCE EVALUATION

A. B. Руснак,

*д. е. н., професор, професор кафедри економіки, Херсонський навчально-
науковий інститут Національного університету кораблебудування імені
адмірала Макарова, м. Миколаїв, Україна*

Д. А. Ломоносов,

*к. е. н., доцент, доцент кафедри економіки, Херсонський навчально-науковий
інститут Національного університету кораблебудування імені адмірала
Макарова, м. Миколаїв, Україна*

ФУНКЦІЇ, СТРУКТУРА ТА ПОКАЗНИКИ ОЦІНКИ ЕФЕКТИВНОСТІ НАЦІОНАЛЬНОЇ ІННОВАЦІЙНОЇ СИСТЕМИ

The article defines the sequence of stages of the innovation system analysis in the functional approach. The foreign experience of grouping functions which should carry out the national innovation system (NIS) is studied. The functions of the national innovation system as a flexible response, selection, stimulation, innovation and generative are analyzed. The main functions of the national innovation system are highlighted and justified: formulation of innovation policy as guidance for all elements of the innovation system in terms of their role and functions within the system, as well as directions of development (i.e. goals to be achieved); providing regulatory and legislative framework; identification and selection of priorities in innovation and research and development with the highest economic or social impact; mobilization and placement of resources; implementation of research; creation of human capital; provision of incentives for the development of innovation; support for the development of new (high-tech) industries and services. The structure of NIS has been summarized. It contains priorities and strategy of innovative policy; normative-legal base in the sphere of development and stimulation of innovation activity; innovative infrastructure; system of generation and distribution of knowledge; innovative companies; institutions in education; market conditions promoting the introduction of innovation; marketing and financial components of creation and innovation promotion; interaction with the international environment; mechanism of innovative development. The key characteristics and main regularities of NIS development are defined. Hence, the NIS development basic principles were formulated. On the basis of the identified patterns of NIS development the basic requirements for NIS are summarized. The key indicators of a level and conditions estimation of national innovative system development are generalized, in particular: indicators of the reached level of scientific and technical development, qualitative indicators of market institutes and the legislation development, indicators of workforce educational level, financial indicators, indicators of transfer and use of knowledge, quantitative and qualitative indicators of economic growth.

У статті визначено послідовність етапів аналізу інноваційної системи

при функціональному підході. Вивчено зарубіжний досвід щодо групування функцій, які має виконувати національна інноваційна система (НІС). Проаналізовано такі функції національної інноваційної системи як гнучкого реагування, селекційну, стимулювання, інноваційну та генеративну. Виділено та обґрунтовано основні функції національної інноваційної системи: формулювання інноваційної політики як керівництва для всіх елементів інноваційної системи у частині їх ролі та функцій у межах системи, а також напрямів розвитку (тобто цілей, які необхідно досягти); забезпечення нормативно-законодавчої бази; ідентифікація та вибір пріоритетів у галузі інновацій та наукових досліджень та розробок, які мають найвищу економічну чи соціальну дію; мобілізація та розміщення ресурсів; здійснення науково-дослідної діяльності; створення людського капіталу; надання стимулів для розвитку інновацій; підтримка розвитку нових (високотехнологічних) галузей промисловості та сфери послуг. Узагальнено структуру НІС, яка містить: пріоритети та стратегію інноваційної політики; нормативно-правову базу у галузі розвитку та стимулювання інноваційної діяльності; інноваційну інфраструктуру; систему генерації та поширення знань; інноваційні підприємства; установи у сфері освіти; ринкові умови, які сприяють впровадженню інновацій; маркетингову та фінансову складові створення та просування інновацій; взаємодію з міжнародним середовищем; механізм інноваційного розвитку. Визначено найважливіші характеристики та основні закономірності розвитку НІС. На цій основі сформульовано базові принципи розвитку НІС. На підставі виявлених закономірностей розвитку НІС та з урахуванням базових принципів узагальнено основні вимоги до НІС. Узагальнено основні показники оцінки рівня та умов розвитку національної інноваційної системи, зокрема: Показники досягнутого рівня науково-технічного розвитку, якісні показники розвитку ринкових інститутів та законодавства, показники освітнього рівня трудових ресурсів, фінансові показники, показники передачі та використання знань, кількісні та якісні показники економічного зростання.

Keywords: *innovation, national innovation system, innovation development, assessment, efficiency.*

Ключові слова: *інновації, національна інноваційна система, інноваційний розвиток, оцінка, ефективність.*

A Problem Statement. The current stage of economic system development is characterized by the mandatory formation of state innovation systems. In this context, the issue of their content and assessment is of particular relevance, which involves the specific methodological framework formation. Such a base should contain essential parameters that allow identifying qualitative and quantitative characteristics that meet modern human needs and forecasts its development, together with a system of adaptive tools, considering the acceleration of changes both within and outside national innovation systems.

Analysis of recent research and publications. The problem of forming an effective national innovation system is the research object of leading foreign scientists, such as: A. Johnson [1], A. Paterson, R. Edam and J. Mullin [2], M. Heckert and S. Negro [3] and others. The leading domestic scientists L. Antonyuk, Y. Bazhal, V. Geyets, V. Gurova [4], L. Fedulova and others study foreign experience in the formation and functioning of national innovation systems in the context of building NIS in Ukraine.

The formation of the national innovation system (NIS) and its effective activity organization is a principal factor in improving the economic competitiveness, but the structure of NIS and the generalization of indicators to assess its effectiveness requires further development.

The objective of the article. The paper aims to identify the functions and research the structure and generalization of indicators to assess the effectiveness of the national innovation system.

Presenting the main material. Innovative activity is inherent in humanity during the entire long evolution of its development; never before has its importance been as crucial as at the current stage of development. The essence of a new society is

the constant reproduction and implementation of innovations [5, p. 40].

The first sign of innovativeness is high knowledge intensity (the share of expenses on research and development in the company's sales); the second sign is a high share of new products or services in the structure of a company or industry output (sales, production. In this case, we are talking about the so-called linear models of assessing the degree of innovativeness. The next step in measuring innovation is more complex notions of innovation processes that are non-linear, random, and dependent on past development [6, p. 64].

According to practitioners, the mechanism for the rapid assessment of national innovation systems is functional analysis. The functional approach implies a particular sequence of stages in the innovation system analysis (Fig. 1).

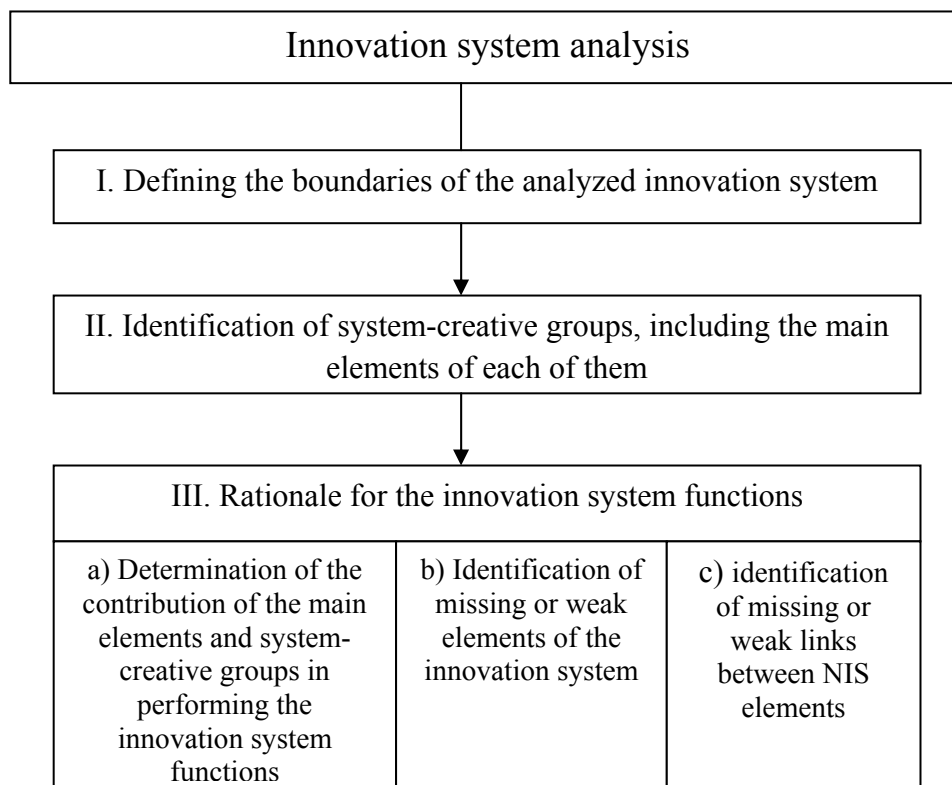


Fig. 1. Stages of innovation system analysis in the functional approach

When considering a national innovation system, the first stage is easy to go through, but analyzing sectoral or sub-sectoral systems is not so easy. The second step involves identifying the main elements in each of the following systemic groups: the private sector; the public sector (including policymaking, coordination, financing

and regulatory bodies); the research sector; technology transfer companies and other intermediaries; public organizations; and foreign partners.

The third stage, which involves defining the main functions of the innovation system, is associated with difficulties, since there is no agreed list of such functions in the scientific literature.

The essence of NIS can be revealed through its functions. A. Paterson, R. Edam and J. Mullin, studying the practices of different countries, compiled a list of functions that should be performed by the national innovation system. They divided this list into two groups [2]:

1) functions that are the prerogative of the central government:

- formulating policies and allocating resources at the national level;
- providing specialized advice;
- regulatory policymaking;
- implementation of international scientific and technical relations;

2) functions that the central government performs together with the third parties (public research organizations, private sector, non-governmental organizations):

- financing of activities related to innovation;
- R&D and innovation implementation;
- networks and flows of knowledge transfer creation;
- development of human resources capacity;
- technical services and infrastructure development.

The main feature of the list of functions is the emphasis on the role of government in the innovation system, as the subject of the scientists' research was the public sector. Therefore, other authors suggest other functions.

According to A. Johnson: "The goal of an innovation system may be said to be to develop, diffuse and utilize innovations" [1]. Having analyzed the use of functional analysis in the works devoted to innovation systems, A. Johnson identified a list of general functions that an innovation system should perform; in particular, she identified two main functions directly related to the innovation process:

- 1) the function of identifying problems;
- 2) the function of developing solutions to the identified problems (i.e. to create new knowledge).

A. Johnson noted some support functions indirectly influencing innovation, in particular: to supply incentives for companies to engage in the innovative activity; to supply necessary resources (finances, qualified personnel, R&D infrastructure); to guide the direction of search (influencing the direction of resource allocation); to recognize the potential for growth of the innovation (technology capabilities, successful market strategy); to facilitate the exchange the information and knowledge; to stimulate and create markets for innovation; to reduce social uncertainty of markets [1].

M. Heckert and S. Negro distinguish the following functions of national innovation systems:

- 1) entrepreneurial activity;
- 2) knowledge development (learning);
- 3) knowledge diffusion through networks, i.e. information exchange;
- 4) guidance of the search;
- 5) market formation;
- 6) resources mobilization;
- 7) creation of legitimacy/counteract resistance to change [3].

Later they are once again provably limited to just the listed seven functions [7].

E. Hasanov identifies five main functions of NIS: flexible response; selection; stimulation; innovation and generative one [8]. In our opinion, the listed functions are rather functions of the whole economic system. The analysis of these functions confirms this judgment (Table 1).

In our opinion, the main functions of the national innovation system are:

- 1) formulation of the innovation policy as a guide for all elements of the innovation system in terms of their role and functions within the system, as well as directions of development (i.e. goals to be achieved);

Table 1. Functions of National Innovation System

Function	Function characteristics
Flexible response	Provides a rapid response to all changes in the national and world economy, there is a discovery on this basis of new non-traditional factors of production. Potential flexibility is the ability of the system to respond to changes in input and output values, as well as production conditions without losing stability and efficiency. The level of this flexibility depends on the ability to quickly compensate for changes in requirements without disrupting the internal flow of the process. Factors that determine the potential flexibility of the system are the flexibility of the individual elements of the system and the degree of their interaction.
Selection	It consists in establishing a special regime for certain types of information and technology, considering their content and purpose of use, thereby encouraging or restraining their dissemination.
Stimulation	Stimulates the formation of new factors, types, forms, organization of information production in the national economy. The function of stimulation is understood as all factors making it possible to influence any activity and positively affect its functional or qualitative properties.
Innovation	Consists of factors contributing to the development of new knowledge and information, the implementation of technical changes, and the emergence of new market relations. This is a complex of scientific, industrial-technological, managerial, marketing and other knowledge, new in relation to previously accumulated.
Generative	Its implementation involves spreading new information and innovative technologies to all spheres of the economy and society. This function facilitates the perception by producers of scientific, technological and organizational innovations, their mass distribution and their displacement of conventional ones. In the process of perception and dissemination in production, the technology loses its market novelty and becomes traditional. With the emergence of a new generation of innovations, the process is repeated.

2) provision of regulatory and legal framework: considering the number of participants of the innovation system and often contradiction of their interests, the necessary set of regulations and laws (in the field of intellectual property rights, fair competition, technical standards, health and ecology, etc.), which create equal and fair conditions for all participants of the system;

3) identification and selection of priorities in innovation and research and development with the highest economic or social impact;

4) mobilization and allocation of resources: the availability of resources to finance innovation activities is usually limited, so they must be mobilized and allocated. There are different ways of effective use of budgetary resources, as well as various forms of financing of science and innovation by the business sector;

5) implementation of research activities: this function ensures the functioning of scientific and innovation organizations, determines the scale and efficiency of results;

6) creation of human capital: investments in human and physical capital are long-term strategic decisions;

7) providing incentives for the innovation development: the government can implement incentive policies in the form of financial incentives (tax vacations, subsidies, etc.), as well as through intangible incentives (prestige and recognition);

8) support for the new (high-tech) industries and services development: innovation activity and knowledge intensity of the economy is largely determined by its structure.

The most important characteristics of NIS are:

- the presence of branched interaction between the subjects of innovative activity;
- the cross-cutting and multi-level nature of the interrelations within the system;
- The presence of a number of different components (elements);
- The decisive role in the formation and development of NIS is played by the state;
- it is an integral part of the economic system of the country and serves as a link between macroeconomic policy, science, the educational system, high-tech industry and the market;
- it is aimed at achieving the strategic goals of the macrosystem;
- produced knowledge, technologies, innovations within NIS should be competitive both within the country and on the world market.

The simplest model describing the interaction of elements of NIS is that the role of the private sector is to develop technologies based on their own research and in the market development of innovations, the role of the state in promoting the production of fundamental knowledge and a set of technologies of a strategic nature, as well as in creating infrastructure and favorable institutional conditions for innovative activities of private enterprises. Different variants of this model implementation in the conditions of socio-economic development of each country form the national characteristics of innovation systems.

Based on the analysis and synthesis of studies of the innovation system elements by domestic and foreign economists, the structure of NIS is summarized, containing:

- 1) priorities and strategy of innovation policy;
- 2) normative-legal base in the field of development and stimulation of innovation activity;
- 3) innovation infrastructure;
- 4) system of generation and distribution of knowledge;
- 5) innovative companies, including large scientific and industrial companies, high-tech industrial creation;
- 6) institutions in the field of education and vocational training: training in the organization and management in the field of innovation;
- 7) market conditions conducive to the implementation of innovation;
- 8) marketing and financial components of creating and promoting innovation;
- 9) interaction with the international environment;
- 10) mechanism of innovative development, reflecting the system of relations between the above elements.

In addition to these elements, it is necessary to consider a set of social, political, cultural and international factors directly affecting the dynamics and nature of the innovation system development within national borders.

This set of elements is necessary and sufficient for the development of NIS because the exclusion of any component leads to a break in the innovation process and therefore makes the entire system impossible to function. All elements are equivalent in the process of formation and development of NIS. Components of the innovation environment do not exist in isolation but are in close functional interdependence. Strategic management of NIS is carried out by changing the external parameters, the values of which are defined in the framework of macroeconomic policy, and the mechanisms of achieving them are set by law.

The scale and level of development of individual components and the nature of forward and backward linkages determine the differences in the innovation systems

of different countries.

The formation of NIS is individual for each country and is determined by the existing socio-economic relations. However, in each case, some approaches and tools can be used, which have proved their effectiveness in other countries. The main regularities of NIS development have been identified:

- the state plays an active role in the formation and functioning of the NIS;
- the role of the state in the management of economic processes is changing with the formation of NIS;
- the transition from direct to indicative management;
- development of technologies, primarily, information and telecommunication, contributing to the creation of network structures, the management of which is based on synergistic principles (self-organization);
- the role of regions in the innovation processes development is increasing, and the innovation system is seen as a tool for the development of territories;
- as national innovation systems develop, they are being integrated into supranational ones, which corresponds to globalization processes.

Most scientists observe the general methodological principles of NIS development [4, p. 156]:

- knowledge plays a specific role in economic development;
- the main factor of economic dynamics is competition between entrepreneurs, which is based on innovation;
- the institutional context of innovation activity has a direct impact on its content and structure.

Considering the identified patterns, a number of basic principles of NIS development were formulated:

1) knowledge is a strategic resource of economy of post-industrial society, innovation activity becomes a determining factor of its development, and the national innovation system - the institutional basis;

2) NIS is formed and develops in stages, differing in the level of development of the factor system;

3) NIS is formed on the basis of the balanced application of state and market mechanisms of economic regulation, taking into account the features and level of socio-economic development of specific territories.

Considering the identified patterns of NIS development and taking into account the basic principles, we can summarize the main requirements for NIS:

- ensuring the growth of competitiveness of knowledge-intensive products and the country's economy as a whole;
- sufficient stability ensuring normal functioning of NIS in the changing economic situation
- the transformation of NIS into a tool for development of depressed regions and reducing the differentiation in their socio-economic development;
- the ability to integrate into the innovation systems of the highest level.

The NIS development strategy is determined by state macroeconomic policy, normative and legal support, forms of direct and indirect state regulation, the state of scientific, technological and industrial potential, domestic commodity markets, labor markets, as well as historical and cultural traditions and characteristics.

The above approaches to the formation of NIS are general and can be used in the development of innovation policy, and implement the strategic objectives of the economic development of the country. At the same time, if the state strategy is aimed at the transition to a post-industrial society, the process of formation of NIS can be considered the initial stage of its implementation. In this case, it will be necessary to revise the views on innovative activities, in particular, the spread of innovative approaches not only to the sphere of production technology but also to the industries that provide vital activity and meet human needs - education, health care, culture.

There are some different indicators assessing the level of the innovation system development, its potential. The formation of indicator system for evaluating the NIS effectiveness is based on national features of its formation and development priorities, so it should include an assessment of all stages of the innovation cycle and related processes. Such a system usually contains aggregated and partial indicators. The most appropriate measure for an objective evaluation of the innovation system

effectiveness is the ratio of changes in costs and results. At the same time, intensive development of the macrosystem is only one of the possible options, and in addition, efficiency can also be described by qualitative indicators (state of the legislative environment, level of infrastructure development, etc.).

Among a variety of indicators used in various methods to assess the effectiveness of NIS, it is possible to identify a set of key indicators to evaluate the level and conditions of development of the innovation system as a whole (Table 2).

Table 2. The main indicators of the assessment of the national innovation system level and conditions of development

Group of indicators	Indicators
Indicators of the achieved level of scientific and technological development	- average age of scientific equipment (years); - the share of innovation-active companies in their total number in the industry; - the level of innovation activity of industries (the ratio of the volume of expenditures on innovation to the volume of current and capital expenditures of enterprises of the industry); - the share of advanced production technologies (APT) that have been used for less than three years to the total number of APT (%)
Qualitative indicators of the market institutions and legislation development	- level of bureaucratization; - the number of small businesses in the innovation sphere
Educational level of the workforce	- the average age of researchers with a degree (years); - the degree of susceptibility to innovations by the personnel of the enterprise
Financial indicators	- expenditures on research and development (in % of GDP); - share of innovation costs in the total volume of industrial output (%); - efficiency of expenditures on innovation activities
Indicators of knowledge transfer and use	- the share of innovative products in the volume of industrial production (%); - number of patent applications for inventions per 10 thousand people; - the ratio of the number of patent applications filed by national applicants abroad and in the country; - specific weight of the country in the international trade in technologies (%); - import dependence of innovation activity (the ratio of the cost of purchasing imported technologies to the industry's expenditures on innovation)
Quantitative and qualitative indicators of economic growth	- life expectancy; - GDP per capita; - environmental characteristics; - level of competitiveness of the national economy

Indicators for assessing the NIS effectiveness are, in particular, a reflection of the conditions under which it is formed and develops. More often the characteristics of an effective NIS contain:

- sustainable development and functioning of the macrosystem subjects;

- priority of innovative type of development;
- clear definition of NIS objectives;
- availability of effective state policy in the sphere of innovation activity development;
- a limited number of priority (critical) areas of scientific and technological development;
- ability of the educational sphere to provide the need for specialists of appropriate qualifications in the field of innovation activity;
- ability of the financial system of the country to provide the necessary resources for innovation activity;
- readiness of the industrial sector to perceive innovations of the world level and to respond to changes in the competitive environment;
- high level of innovation activity information support.

Conclusions. The national innovation system is a set of economic entities (enterprises, research organizations, consumers) and institutions (legal, legislative, financial, social), interacting in the production, distribution and use of competitive knowledge and technology aimed at implementing the strategic objectives of sustainable development of the economic system and contribute to the competitiveness of its subjects, including states at the international level.

The most important characteristics of NIS: the interaction between subjects of innovation activity; end-to-end and multi-level nature; containing a number of interrelated components (elements); the decisive role in its formation and development belongs to the state; is an integral part of the economic system of the country and acts as a link between macroeconomic policy, science, education, high-tech industry and the market; aims to subordinate the objectives of the macro system at all stages of the innovation process; produced knowledge.

Further research and development requires a model of interconnection of the main elements of the national innovation system, which has the properties of integrity, certainty, observability, universality, constructability, flexibility and adaptability to constant changes in the internal and external environment.

Література

1. Johnson A. Functions in Innovation System Approaches. Goteborg, Sweden: Department of Industrial Dynamics, Chalmers University of Technology, 1998. URL: www.druid.dk/conferences/nw/paper1/a_johnson.pdf (дата звернення: 30.01.2022).
2. Paterson A., Adam R. and Mullen J. The Relevance of the National System of Innovation Approach to Mainstreaming Science and Technology for Development in NEPAD and the AU. Pretoria: NEPAD, 2003.
3. Hekkert M.P., Negro S.O. Functions of Innovation Systems as a Framework to Understand Sustainable Technological Change Empirical Evidence for Earlier Claims. 2005. URL: www.geo.uu.nl/isu/pdf/isu0810.pdf (дата звернення: 25.03.2022).
4. Гурова В. Методологія та ключові детермінанти побудови ефективної національної інноваційної системи. *Міжнародна економічна політика*. 2015. № 2 (23). С. 149-169.
5. Silberglitt R; Philip S. Antón, Howell D. Wong A. and Bohandy S. Global Technology Revolution 2020: Technology Trends and Cross-Country Variation. Innovation Vital Signs. Final Report. Santa Monica, CA: RAND, 2006.
6. Innovation Measurement: Tracking the State of Innovation in the American Economy. Department of Commerce USA. URL: www.innovationmetrics.gov (дата звернення: 28.04.2022).
7. Hekkert M.P., Suurs R.A.A., Negro S.O., Kuhlmann S., Smits R.E.H.M. Functions of innovation systems: A new approach for analyzing technological change // *Technological Forecasting & Social Change*. 2007. №74. Pp. 413-432.
8. Гасанов Э.А. Инновационный вектор развития информационной экономики. *Инновации*. 2004. №5. С. 10-14.

References

1. Johnson, A. (1998), "Functions in Innovation System Approaches", available at: www.druid.dk/conferences/nw/paper1/a_johnson.pdf (Accessed 30 Jan 2022).

2. Paterson, A., Adam, R. and Mullen, J. (2003), "The Relevance of the National System of Innovation Approach to Mainstreaming Science and Technology for Development in NEPAD and the AU", Pretoria: NEPAD, South Africa.
3. Hekkert, M.P. and Negro, S.O. (2005), "Functions of Innovation Systems as a Framework to Understand Sustainable Technological Change Empirical Evidence for Earlier Claims", available at: www.geo.uu.nl/isu/pdf/isu0810.pdf (Accessed 25 Mar 2022).
4. Gurova, V. (2015), "Methodology and key determinants of building an effective national innovation system", *Mizhnarodna ekonomichna polityka*, vol. 2(23), Pp. 149-169.
5. Silberglitt, R., Philip, S., Antón, Howell, D. Wong, A. and Bohandy, S. (2006), "Global Technology Revolution 2020: Technology Trends and Cross-Country Variation. Innovation Vital Signs. Final Report", Santa Monica, CA: RAND, USA.
6. Department of Commerce USA (2001), "Innovation Measurement: Tracking the State of Innovation in the American Economy", available at: www.innovationmetrics.gov (Accessed 28 Apr 2022).
7. Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., Smits, R.E.H.M. (2007), "Functions of innovation systems: A new approach for analyzing technological change", *Technological Forecasting & Social Change*, vol.74, Pp. 413-432.
8. Hasanov, E.A. (2005), "Innovative vector of information economy development", *Innovacii*, vol. 5, Pp. 10-14.

Стаття надійшла до редакції 27.05.2022 р.