Pavlov K.V.
Dr. Sci. (Econ.), Prof., head of Department of Economics
Kamsky Institute of Humanitarian and of Engineering Technologies

STATISTICAL MEASURING OF THE DEVELOPMENT OF NANOECONOMICS

Statement of the problem. Contemporary social and economic development of the leading states is largely determined by the effective use of resources and factors of Scientific and Technological Progress. The share of technological innovations in GDP of developed countries is between 70% to 90%. And great attention has been recently paid to the development of nanotechnology – scientific and technological sector which was formed at the intersection of physics, chemistry, biology, medicine and materials science. According to experts, nanotechnology will be able to make a revolution in society in the foreseeable future, and by its scale it will exceed even the consequences of widespread use of computers.

Nanoindustry has been producing materials and products of super small size by examining the properties of various substances at the molecular and atomic levels. In the metric system nanometer (nm) – and it is from this word occurred prefix “nano” in the term “nanotechnology” – corresponds millimicron (which is the unit of length equal to one billionth of a meter, or 10^{-9}). For comparison, the thickness of a human hair is on average 50 000 nm [1].

And although there is not a comprehensive definition of “nanotechnology" at present yet, one can say, by analogy with microtechnologies, that nanotechnologies operate with quantities of the order of one billionth of a meter.

In general, under the nanotechnology one usually understands a set of methods and techniques, which provide an opportunity in a controlled manner to create and modify objects, including components smaller than 100 nm in at least one dimension and as a result receiving a fundamentally new quality, allowing to carry out their integration into a fully functioning systems of bigger scale. In a broader sense, nanotechnologies also include methods of diagnosis and study of such objects.

In addition to nanotechnology when considering the development of nanoindustry one should also take into account the development of nanomaterials and nanosystem technology that are the constituent elements of nanoindustry [2]. Nanomaterials are materials which have structural elements, the geometrical size of which is at least in one dimension less than 100 nm and due to this they have qualitatively new features, including specified functional and operational characteristics. A nanosystem technology is generally understood as functionally complete systems and devices which were created fully or partially on the basis of nanomaterials and nanotechnology and their characteristics are drastically different from those systems and devices of similar purpose, created by traditional technologies. Thus, nanoindustry is an activity to create products based on nanotechnology, nanomaterials and nanosystem technology.

Analyzing the development of nanoindustry, one should bear in mind that in this case he is expected to consider the widest range of diverse and not always directly connected problems in different areas of science and technology, which already use the appropriate technologies and methods. Although nanotechnology is not therefore appropriate to consider as a whole, but more like a generic term, it should be acknowledged that the nanoindustry as a whole has a revolutionary impact on the development of information and communication technologies, biotechnology, safety equipment and many others. As a result, dozens of countries have recently adopted national programs of nanoindustry development as the highest national priority. There are such developed countries as the USA, Japan, Germany, France, China and others among them.

Thus in China, for example, there have recently been about 800 companies engaged in the implementation of nanotechnology, as well as more than 100 core scientific and research institutions, the vast majority of which are focused on meeting the needs of the military-industrial complex of this country. Other developed countries also allocate huge funds to defense developments in nanotechnology. Russia by the volume of total costs of nanotechnology development is among the leaders, and, there are large centers of nanotechnology development in more than 20 entities of the Russian Federation (for example, in such cities as Belgorod, Izhevsk, Cheboksary, etc.).

Analysis of recent research and publications. Analysis of recent publications shows that often instead of the term “system of nanoindustry” the term “nanoeconomics” is more often used, and we understand nanoeconomics as the system of reproductive relations connected with the production and use of nanotechnology, nanomaterials and nanosystem technology. However, there is another way of using the term “nanoeconomics”. Thus G. Kleiner identifies 5 hierarchical levels: mega-, macro-, meso-, micro- and nanolevel, as well as corresponding economic subjects: international economics, macroeconomics, mesoeconomics, microeconomics and nanoeconomics [3]. Relations of single labor division and cooperation of individual employees, competition and monopoly of individuals on knowledge, habits and skills within professional groups, the formation and realization of the values and usefulness of their work is the object of study of economic theory at the nanolevel. Therefore in this sense a separate individual, a person is an object of nanoeconomics. In our view, both approaches have the right to exist, but in the future we will stick to the first one. Except RAS Corresponding Member G. Kleiner, problems of development of nanoindustry

were also investigated by such famous Russian and Ukrainian scientists as academicians of NAS of Ukraine N.G. Chumachenko and A.I. Amosha, professor V.I. Lyashenko, M.I. Shishkin, A.S. Flerov and others.

At the same time one of the biggest problems in the national economy in the field of nanotechnology is the problem of the mass introduction of inventions and patents obtained by the creation of nanomaterials and nanotechnology. These sorts of problems as it is known are one of the key ones in Russia R & D since the Soviet times (kind of the Achilles heel of this sphere). Another serious problem of the effective development of nanoindustry is undeveloped statistical system of nanoindustry's development.

Statement of the problem. The article aims at the development and establishment of a system of indicators characterizing in various aspects the current state and dynamic parameters of development of nanoindustry. For the effective development of nanoeconomics it is very important to create the system of indicators, which provides an integrated approach and at least all the main aspects and elements of the formation and development of nanoeconomics are taken into account. There must be a chapter in this system where the indicators characterizing the development of nanoeconomics in general and at different levels of the management hierarchy: at the global and international level, at the national, sectoral and regional levels, as well as at the level of the individual enterprise (organization) and its separate business units are considered.

The specified system should primarily include such indicators as the total volume of the development and use of nanoproducts, expressed in cost parameters and natural units of measurement, as well as the total cost of the creation and implementation of such products at different levels of the management hierarchy. Besides, this group of indicators must include indicators characterizing specific weight, share of the value of nanoproducts in total production value, which is produced by this business entity. One should also include indicators characterizing social and economic efficient use of nanoproducts and nanoindustry as a whole - as common performance indicators as well as private indicators (labor productivity, capital productivity, consumption of materials, capital intensity, etc.).

The main material of the study. Very important indicator is an indicator of science intensity characterizing the technology and showing the degree of its connection with scientific research and development. In this case, the technology is understood as a set of methods and techniques used in all stages of development and manufacturing of a certain type of products [4].

The science intensive technology means the technology that includes amounts of experimental work, exceeding the average values of this indicator of technology in a specific field of economics and science intensity is most often seen in the manufacturing sector [5]. It is extremely difficult to assess nanoproducts' science intensity.

Science intensity of sectors is usually measured as the ratio of total costs to the costs of sale, as well as the ratio of the volume of sales to the number of scientists, engineers and technicians working in the industry. High-tech product is a product that has higher R & D expenditures in its cost than average in other spheres of the economy.

The dynamics of nanoeconomics is characterized by such indicators as growth and increase of nanoproducts, the growth rate and the increase rate of it. Structural changes are characterized by such indicator as change in the share of nanoproducts value in the total cost of production of this business entity (enterprise, industry, region, national economic complex as a whole).

Any industrial product is characterized by a certain level of quality, which is currently one of the most important characteristics of the degree of product competitiveness. Improving the quality is especially important for domestic goods in the present time when Russian economy is trying to make the transition from raw materials-type of economy to a developed modern innovative economy. The formation and development of nanoindustry is one of the key areas of implementation of such transition, and therefore the issue of assessing the quality level of nanoproducts is particularly acute. The most important aspect of product quality is its reliability, i.e. the property of products to keep over time within certain limits the values of all indicators characterizing the ability to carry out certain functions in specific modes and conditions of use, maintenance, repairs, storage and transportation.

Reliability is an important property of nanoproducts and therefore parameters of reliability are the main indicators characterizing the quality of products. These indicators reflect the ability of nanoproduct over time to implement the required functions in a given system. These indicators characterize features of faultlessness, durability, maintainability and conservation. Faultlessness is the ability of nanoproduct constantly to keep working for a certain period of time or specific developments, which manifests itself in the possibility of failure-free activity. Maintainability is the property of nanoproducts, which is consists in its adaptability to prevent and detect the causes of denials, damages and liquidation of their consequences as a result of repairs and maintenance. Restoration of nanoproducts is determined with average recovery time to a certain value of the quality index and degree of resumption. Persistence is the ability of nanoproducts to keep in good and workable condition that is suitable for use and operation in the period of time after storage and transportation. Average storage time and the designated retention period are indicative of the conservation. Durability is the ability of nanoproducts to save before limit condition in the timing of maintenance and repair. Average resource and an average life are indicators of durability the term "resource" is used in the characterization of durability product on an operating time this product, and the

“service life” – in characterizing the durability according to the calendar period of time. At the same time is isolated the unit reliability index, which characterizes one of the qualities of nanoproducts and comprehensive indicator characterizing several qualities that make up the reliability of nanoproducts.

It is also very important to determine the indicators of manufacturability of nanoproducts. The most important indicators of this group are such as specific material consumption of nanoproducts, its specific labor input of manufacturing, energy intensity of manufacturing and operation of nanoproducts and the average operational duration of the maintenance of these nanoproducts. Overall, the indicators of manufacturability express the generalized characteristic of rationality that are applied in product of design and technological solutions and the best distribution of expenditures at all stages of the life cycle of nano-products.

The actual problem of statistical evaluation of manufacturability is not only of nanoproducts in general, but also composite nano-elements in complex construction. Manufacturability of design is a property that reflects how well the requirements are taken into account of available technology and system of the development of production, transportation and maintenance of products. Technological design provides the minimization of duration of the production activity and material consumption at all stages of the life cycle of product. The main indicators of the technological design, which include nanoelements, are: specific gravity of nanodetails in their total amount in this product, the coefficient of inter-project unification (i.e. borrowing) of nanoelements of the device, the coefficient of unification of nanoprocesses manufacturability and several others.

Considering that in the development of nanoindustry in Russia, serial and mass production of nanoproducts is one of the least efficient units at the present time. The great importance is the development of indicators of standardization and unification of nanoproducts, reflecting the degree of application of the standard, unified and unique components of the product. Let’s remind that standardization is a system of development and definition of requirements, rules and regulations, specifications that are expressed in the standards, both mandatory and recommended for implementation in the production process. Standardization is a very significant factor in improving product quality and accelerating STP at different levels of the social hierarchy.

Unification is one of the methods of standardization. Unification is the achievement the objects identically constructive purpose to the unique form by certain quality and rational reducing the number of these objects on the basis of information about their effective use. Necessary but not a sufficient amount of types, varieties, sizes, components, details having high quality and interchangeability are determined during unification. Unified requirements are appeared to the quality of nanoproducts, labor protection and working conditions of employees in enterprises due to standardization and unification.

The coefficients of applicability, repeatability of component parts of nanoproducts, unification of products, new and original design, mass production, economic efficiency of standardization of nanoobject are related to the coefficients of standardization and unification. Coefficients of repeatability and unification on design components are also calculated in addition to these indicators. Thus, the indicators of standardization and unification characterize the saturation of goods with the ordinary, standardized components, which are included in a design, equipment, assemblies, kits, etc. One of the major directions and methods of standardization is aggregation, which is defined as a way of creating machines, installations, structures, components, devices and other products from the unified units, installed in the product and in varying amounts in different combinations.

Great importance is the development of indicators that characterize the innovative activity of social and economic systems at different levels of the management hierarchy. Thus, the level of innovation activity reflects the indicator of the specific gravity of enterprises and organizations (in the region, the industry, in the national economy as a whole), implementing technological, organizational and marketing innovation in the field of nanotechnology in the total number of enterprises and organizations. The similar indicator for the separate enterprise is expressed as the proportion of guild and other structural subdivisions of the enterprise exercising nanoinnovations in the total number (as in the total number of innovatively active subdivisions and the specific gravity of the whole). Apart from this index the level of innovation activity and saturation of the market of nanoproduction also characterizes the indicator of the specific gravity of nanogoods, works and services in the total volume of innovative products, works and services, as well as in the total volume of shipped goods, executed works and services organizations.

It is appropriate to calculate the intensity of costs on technological nanoinnovations as the ratio of expenditure on technological nanoinnovations to the volume of shipped goods and completed works. It is important to determine the specific gravity of small, medium and large enterprises engaged nanoinnovations, in total number respectively of small, medium and large enterprises for more detailed analysis. It should also to calculate indicators of the specific gravity of exports and imports of nanogoods and nanotechnologies in the total volume respectively of exports and imports.

Another important group of indicators are indicators that characterize the efficiency and effectiveness of nanoindustry in the industry, in the region and the national economy as a whole. These indicators include indicators of cost recovery of nanoinnovations (it is the ratio of the volume of nanogoods, works and services to the amount of expenditure on researches, development and acquisition of nanoinnovation) release of

nanoproducts in average per capita, the ratio of the number of advanced nanotechnology used to the number of created nanotechnology as well as the ratio of nanogoods, works and services to the number of innovative enterprises. Some researchers suggest that in the most regions of Russia, for example, the relationship between the innovation developments and efficient of territorial reproduction is very weakly expressed [6].

Exacerbation of environmental issues necessitates of statistical accounting degree of harmful effects on the environment arising during the production, using and operation of nanoproducts [7]. For the quantitative estimation it also used indicators of environmental of products, which is one of the fundamental properties that determine the level of its quality. The main indicators of environmental of nanoproducts include indicators such as the content of harmful impurities in nanoproducts, emissions of harmful substances into the environment due nanofabrication, evaluation of the level of noise, vibration, radioactive environmental contamination (scientific direction in which we investigate the influence of the development of nanoindustry on the environment can be called nanoecology).

It should consider the feasibility of establishing of other groups of indicators, such as, for example, ergonomic, aesthetic, and other groups of indicators besides of environmental indicators when developing the system of indicators characterizing the formation and development of nanoeconomics [8]. Ergonomic parameters reflect the comfort and convenience of use of nanoproducts. So, psychological indicators are used in establishing of compliance of nanoproducts with capabilities of perception and information processing, as well as psychological qualities of the person. Another variety of ergonomic parameters are anthropometric indices. These indicators are used in establishing of design meets basic product to size, shape and weight of the human body and its individual components coming into the contact with nanoproducts. This category also includes hygienic, physiological and physiological indices.

So, health indicators are used to establish of compliance of nanoproducts with hygienic applications of life activity and human performance in its reaction with the product. In other words, health indicators define the product conforms to sanitary standards. Physiological parameters are used in establishing of nanoproducts compliance with the physiological characteristics of the person and the functioning of his sensory organs (for example, conformity of the device of nanoproducts to the power and speed characteristics of the person or design meets of nanoproducts to the visual, physiological and physiological features of the person).

Aesthetic indexes of nanoproducts characterize its aesthetic impact on a person. Indicators in this group are associated with a complex quality – aesthetics, affecting the human perception of nanoproducts in terms of its appearance. This quality is determined by such simple features as form, harmony, composition, style, etc. According to this, aesthetic indicators characterize correspondence of nanoproducts to environment, style, information and decoration of nanoproducts, its harmony and expressiveness, originality of design and packaging, etc.

Conclusions from the study. These groups of the system's indicators represent, in our opinion, the main aspects of the formation and evolution of nanoeconomics (in this regard, this system can be called a system of nanoindicators). The system of nanoindicators thus should include the following sections: general section, section of nanoindicators' dynamics, section describing the quality, standardization level and unification of nanoproducts, section of efficiency and innovation activity of nanoindustry, as well as sections describing ecological, ergonomic and aesthetic properties of nanoproducts.

However, it does not mean that over time, the system of indicators characterizing the nanoindustry will not undergo significant changes and new sections of indicators will not be added to it.

It should be added that indicators of all these groups should be considered at different levels of the management hierarchy: mega-, macro-, meso-, micro-and minilevel. This system of indicators may become an element of the emerging now in Russia national and regional innovation systems.

The proposed system of nanoindicators can be used for analyzing the current state and determining development prospects of nanoeconomics not only in Russia but also in other countries, including Ukraine.

References

1. Flerova, A. (2006), "About state regulation of innovative development in the field of nanomaterials and nanotechnologies in Russia", Investments in Russia, no. 8, pp. 41-47.
2. Liashenko, V.I., Pavlov, K.V. and Shishkin, M.I. (2011), "Nanoeconomy in Slavic CIS countries", Knigograd, Izhevsk, 348 p.
3. Kleiner, G. (2004), "Nanoeconomy", Economy Questions, no. 12, pp. 70-93.
4. Perevalov, Y.V. (1997), "Innovative entrepreneurship and the challenges of technological development", Society and Economy, no 7, pp.18-84.
5. Fedulova, L.I. (2006), "The economic nature of technology and technological development", The economic theory, no. 3, pp.3-19.
6. Ivanova, M.V. (2012), "Regional innovation space: features of the development of the knowledge economy in the regions of Russia", Apatity, Kola Scientific Center, Russian Academy of Sciences, 173 p.
7. Ratkin, L. (2006), "Megainvestitsii in nanotechnology", Investment in Russia, no. 1, pp. 39-42.

8. Chumatchenko, B., Lavrov, K. (2001), "Nanotechnology - a key priority for the foreseeable future", Problems of the theory and practice of management, no. 5, pp. 71-75.

Pavlov K.V. STATISTICAL MEASURING OF THE DEVELOPMENT OF NANOECONOMICS

The purpose of the study. The purpose of this paper is developing a system of indicators that allow carrying out the analysis of the present state and characterize the development of nanoeconomics for the certain period of time.

Methodology of research. The methodological basis of the article is a systematic approach to the substantiation of statistical indicators measuring the development of nanoeconomics. Special methods were applied to resolve important problems. Among them are: method of analysis and synthesis – for detailing the object of research due to its division into separate components; abstract and logical – for generalization essence and content of nanoeconomics and indicators its measurement; comparison – for comparison data of various periods of research; monographic – to study and describe the state of development and functioning of the object of research. The relevant state laws and official materials of the state statistics, special scientific resources and information resources of global computer information network Internet were the information base for research. The systemic using of various research methods ensured the development and creation of indicators in various aspects that characterize the present state and dynamic parameters of the development of nanotechnology industry.

Findings. The system of indicators of nanoeconomics was proposed in the research process. Among them are:

- knowledge intensity that characterizes the technology and reflects the degree of connection with scientific research and development;
- the change of share of nanoproducts value in the total value of output that produced by this economic entity (enterprise, branch, region, national complex in general)
- reliability that characterizes the peculiarities of reliability, durability, maintainability and storage
- manufacturability of nanoproducts;
- specific gravity of nanodetails proportion to their total number in this product;
- the coefficient of inter-projected unification (i.e. borrowing) of nanoelements devices;
- standardization and unification of nanoproducts, that reflect the degree of application of the standard, unified and unique ingredients in the product;
- indicators that characterize innovative activity of social and economic systems at different levels of management hierarchy;
- indicators of the specific gravity of goods export and import and nanotechnologies in the total volume according to the exports and imports;
- indicators that characterize effectiveness and efficiency in the area of the nanotechnology industry, the region and the national economy as a whole;
- environmental indicators of products, that are one of the fundamental properties; these indicators determine the level of quality;
- aesthetical indicators of nanoproducts that characterize its aesthetic impact on the person.

All proposed indicators characterize the development of the nanotechnology industry and reflect the main aspects of the formation and development of nanoeconomics. In this system of nanoindicators we should identify the following sections: general, section of the dynamics of nanoindicators, section that characterizes quality, level of standardization and unification of nanoproducts, section of efficiency and innovation activity of the nanotechnology industry and also sections that characterize environmental friendliness, ergonomic and aesthetic properties of nanoproducts.

Originality. It was proposed one of the options of formation of a system of indicators that allows you to analyze the current situation and development of nanoeconomics.

Practical value. Applying of the proposed system of indicators allows analyzing the functioning and development of a new branch of modern industry that is called nanoeconomics that promotes the improvement of statistical study of this perspective industry and provides effective development.

Key words: development of nanoeconomics, the system of indicators, nanotechnology industry, nanoproducts, nanomaterials, nanolevel.