Innovative International Industrial Clusters as a Factor of Developing High-Tech Industry in the Eurasian Economic Union

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Abstract. The paper continues the authors' previous research on the development of high-tech industry in the Eurasian Economic Union (Issues Relating to the Hi-Tech Industry in the Eurasian Economic Union), in which the main features, problems, and ways of development of high-tech bionanotechnology have been determined and the further research areas formulated. In this study, the methodical form of solving previously identified bionanotechnology issues is creating innovative international bionanotechnology (industrial) clusters, including the arrangement of foresight centers within them to ensure convergence of technologies and foresight research and projects in the field of bio- and nanotechnology. To achieve the goal set in the study, a conceptual organizational model of an innovative international bionanotechnology cluster of the Eurasian Economic Union has been developed, the need for creating a foresight center as part of innovative international bionanotechnology clusters justified, and guidelines for its formation and estimation of efficiency elaborated. The further research area is improving the state cluster policy to develop high-tech complexes and scientific justification of creating engineering infrastructure within the innovative international bionanotechnology clusters, including the arrangement of engineering centers within them to provide various engineering services to small and medium-sized innovation enterprises forming the cluster, the performance of joint research and development, the acceleration of transferring technologies to large-scale production, and training staff qualified in bio-nano-oriented engineering.

1. Introduction

This study is based on the authors' previous research devoted to the analysis of issues associated with the Eurasian Economic Union (EAEU) high-tech industry in the field of bio-nanotechnology [1] and continues it with the goal to create the EAEU’s innovative international bionanotechnology (industrial) clusters, including the arrangement of foresight centers within them to ensure convergence of technologies and foresight research and projects in the field of bio- and nanotechnology. Based on the study results, a conceptual organizational model of the EAEU’s innovative international bionanotechnology cluster has been developed, the need for creating a foresight center as part of innovative international bionanotechnology clusters justified, and guidelines for the formation and
estimation of its efficiency elaborated. The research hypothesis is that the methodical form of solving previously identified bionanoindustry issues is creating innovative international bionanotechnology (industrial) clusters, which along with the industrial and investment policies coordinated between the EAEU states, international industrial cooperation, and scientific and industrial partnership are the main tools for developing the EAEU’s high-tech bionanoindustry.

2. Relevance and scientific significance with a brief literature review

The Russian Federation faces a relevant strategic task to ensure Russia's technical breakthrough by 2035, which is dictated by the country’s need for joining the sixth wave of innovation, the global development of the digital economy, and the growing level of digitalizing almost all aspects of life, production, and economy. In solving this issue, the most important role is associated with the development of high-tech businesses, complexes, industries, and branches. In our opinion, it will be difficult for any country to individually make a significant scientific and technical breakthrough; it requires international partnership and cooperation of several countries - the Eurasian Economic Union member states and other interested parties, based on which it is supposed to create innovative international industrial clusters in the field of bionanoindustry, “the development of which may have a great scientific effect and lead to forming a system of new production technologies, creating and manufacturing innovative products based on bionanotechnology” [1, p. 1579].

In scientific publications by different specialists, experts, and researchers, the issue of developing high-tech industry, innovative technologies and potential, science-intensive production, including at the EAEU level, is a relevant and promising area of scientific research. Issues of this scale are mainly resolved at the international level through international industrial cooperation [2, 3]; under the conditions of increasing globalization, states resort to the integration of markets [4], and individual corporations - to the model of generating competitive advantages for sustainable development in the age of economic globalization [5] and other measures. The cluster approach, i.e. creating innovative industrial clusters embodying the synergistic effect of science, finance, industry, and the state is the present-day trend bringing together the advanced ideas of the innovative arrangement of industrial complexes [6, 7, 8]. The arrangement and functioning of virtual teams distributed in space, and in respect to research and experimental development (scientific and innovation projects) participants – the arrangement and functioning of virtual research teams in the form of a consortium [9], which find it difficult to operate effectively without implemented ERP systems with a minimum level of resistance and a high level of commitment and confidence of the staff [10, 11], have become a relevant pattern of coordinating work and cooperation caused by the new coronavirus (COVID-19) pandemic, and solving issues of different nature, including those of pricing for innovative products [12]. Russian authors N.V. Zin’kovskaya, E.V. Mokeeva, and M.A. Tolstopyatenko made a great scientific contribution to studying the formation of the bionanotechnology industrial complexes based on the cluster approach. (N.V. Zin’kovskaya, E.V. Mokeeva, M.A. Tolstopyatenko [13, 14, 15].

3. Research objective

The research objective is determined by the target set and assumes the following:

- developing a conceptual organizational model of the EAEU’s innovative international bionanotechnology cluster,
- justifying the need and developing methodical recommendations for creating a foresight center as part of innovative international bionanotechnology clusters and estimating its efficiency,
- formulating fields (areas) of further scientific research.

4. Theoretical

The research and the results obtained are based on the below scientific analysis techniques: system analysis, the method of comparison and matching the phenomena and processes analyzed, synthesis, generalization, economic data analysis, and organizational simulation. The study is based on the authors’ previous research results, which contain the main conclusion that it is proposed to consider
creating innovative international bionanotechnology clusters, including the arrangement of foresight centers within them to ensure convergence of technologies and foresight research and projects in the field of bio- and nanotechnology, as the methodical form of solving the issues of developing the EAEU’s high-tech bionanoindustry. To create innovative international bionanotechnology clusters and arrange foresight centers within them, a conceptual organizational model of an innovative international bionanotechnology cluster should be developed, the need for creating a foresight center as part of innovative international bionanotechnology clusters justified, and guidelines for its formation and estimation of efficiency elaborated. The fundamental study hypothesis is based on the assumption that the methodical form of solving previously identified bionanoindustry issues is creating innovative international bionanotechnology (industrial) clusters, which along with the industrial and investment policies coordinated between the EAEU states, international industrial cooperation, and scientific and industrial partnership are the main tools for developing the EAEU’s high-tech bionanoindustry

5. The practical significance, the study results, and proposals for further research
The practical significance of the study is concluded in the possibility of applying the scientific results obtained when:
- creating the EAEU’s innovative international bionanotechnology and other industrial clusters,
- arranging foresight centers within the EAEU’s innovative international bionanotechnology and other industrial clusters,
- determining the areas of innovative development of the EAEU’s high-tech industries and industrial complexes.

The Eurasian Economic Union considers the integration of the participating countries in the form of clustering, i.e. cluster development approaches one of the main directions of its development [16, p. 38]. Clustering plays an important role in creating innovative infrastructures. The cluster approach expresses its organizational and economic significance through the formation of a system for disseminating new knowledge and technologies, as well as an aggregate innovative product. Active network interaction of all innovation process participants is ensured by the completeness and harmonious combination of the required cluster elements with informational, economic, and organizational support from the states and the EAEU as a whole. This provides a tangible synergistic effect and serves as the main factor of the innovative development of the entire region, a group of states.

Clusters are characterized by the identity of technologies, a common resource base, and the presence of an innovative component. Expansion of the interaction boundaries leads to the loss of such a cluster feature as the territorial proximity of all participants. The cluster structure generally includes scientific and educational organizations, public authorities, industrial enterprises, and development institutions.

The cluster’s scope of activity is not limited to a single state, the tendency is to create international clusters.

For the EAEU states, creating an innovative international industrial cluster should become a ‘growth point’ of their national economies. An international cluster is understood as “the interaction of interrelated, interdependent, intercomplementary participants located in the territories of two or more countries that operate in related industries, have a similar technology development levels, and are engaged in the joint creation of goods to achieve a synergistic effect in the development of territories and innovations” [17].

To scientifically justify the conceptual organizational model of the Eurasian Economic Union’s innovative international bionanotechnology cluster, let us consider the practical and scientific experience in the field of clusters.

The European Union has extensive experience in creating international clusters [18], e.g., in the field of bionanotechnology, Alsace Biovalley (France, Czech Republic, and Germany) and Nano Öresund (Denmark and Sweden) clusters operate. Such clusters stimulate international scientific,
technical, and industrial cooperation, contribute to the exchange of knowledge and the creation of new science-intensive technologies and world-level high-tech products.

As noted by A.S. Mihaylov, international clusters have a number of features, including competition and cooperation, the obligatory presence of participants from the sphere of universities, business, and government, the continuous development of innovations, etc. The author divides them into cross-border and transnational ones [19]. For the EAEU, cross-border clusters are more typical ones, therefore, in the Main Directions of the EAEU economic development until 2030, it is supposed to “stimulate the creation of cross-border industrial clusters” [20, p. 19]. International clusters are characterized by a longer period of creation, increased risk, and a more complex management system.

The basic organizational model of an international cluster includes [19]:
- an international cluster organization, which comprises various companies, enterprises, and non-profit organizations from agglomerations of cross-border regions,
- universities participating in the creation of a council of universities and an international cluster organization,
- regional authorities participating in the creation of a cross-border committee,
- a cross-border committee and a council of universities participating in the creation of a cluster assistance committee, which also comprises various companies, enterprises, and non-profit organizations from an international cluster organization.

According to the pursued industrial policy, the EAEU member states pay great attention to supporting and developing innovations, including bionanotechnology, and creating an effective innovation infrastructure. However, according to the Global Innovation Index, the participating countries generally demonstrate a lag in innovation development (Table 1).

### Table 1. Rating of the EAEU Countries by the Global Innovation Index.

| Country      | 2016 Rate | 2017 Rate | 2019 Rate |
|--------------|-----------|-----------|-----------|
| Russia       | 43        | 45        | 46        |
| Belarus      | 79        | 88        | 72        |
| Kazakhstan   | 75        | 78        | 79        |
| Kyrgyzstan   | 103       | 95        | 90        |
| Armenia      | 60        | 59        | 64        |

*Drawn up by the authors based on the source [21]*

Belarus and Kyrgyzstan showed positive dynamics having moved up to a higher position; in other countries, the Innovation Index decreased mainly due to the low level of innovation and investment activity of enterprises, insufficient funding for innovation, and a low level of commercialization of innovative technologies.

In this regard, nano- and biotechnologies included in the list of EAEU’s priority economic activities may play a vital role in increasing the innovation level of the EAEU countries’ economies. Integration based on these technologies is assumed to have the form of an innovative international industrial cluster in the field of bionanotechnology. The main feature of the bionanotechnology cluster is its objective innovation orientation. Creating bionanotechnology clusters may significantly increase the level of innovative development of regions.

Currently, there is no single methodology for the creation and development of international clusters.

The methodology for developing the EAEU’s international cluster should consider as much as possible the specifics and potential of regional location of cluster enterprises and may include:
- performing an analysis to estimate and forecast the innovation potential of the regions of the countries participating in the cluster,
- choosing the priority industrial sectors participating in the cluster,
• developing a legal framework in this area,
• availability and potential for the creation of specific elements of innovation infrastructure (technology parks, business incubators, technology transfer centers, venture funds) required for the cluster operation,
• implementing the cluster support mechanisms at both the EAEU and the state and regional levels,
• developing a system of indicators to estimate the cluster operation results.

The cluster model has been analyzed exemplified by a cluster operating in the city of Pushchino. According to the results of the Pushchino Biotechnology Innovative Territorial Cluster infrastructure analysis, its common model includes:
• cluster management bodies comprising a non-profit partnership and a supervisory board,
• the cluster’s scientific core, which comprises specialized scientific institutions of the Russian Academy of Sciences and a number of other organizations,
• anchor enterprises (pharmaceutical and chemical-pharmaceutical manufacturing enterprises, instrument-making enterprise),
• higher educational institutions, basic departments of specialized universities,
• small and medium-sized innovation enterprises,
• infrastructure organizations, including a technology park, a business incubator, and a core facility center.

However, the main elements of the cluster infrastructure should be scientific, educational, innovation, and social components. Consequently, the cluster created should be an innovative model of organization with not only scientific and technological but also social infrastructure (e.g., attracting universities to the cluster to train the required staff and perform research, attracting small and medium-sized businesses to perform research and developments, etc.).

The analysis of the common regional innovation cluster model in the work by M.M. Kandrokova [22] has shown that the author outlines the below components:
• the cluster core, the coordination council, business partners, suppliers, consumers,
• research institutes, laboratories, universities, small innovation enterprises, design bureaus of enterprises,
• technology transfer center, scientific and technical information center, technology and industrial parks, business incubators,
• financial, consulting, and legal firms.

In our opinion, the bionanotechnology cluster model should have some differences, i.e.:
• existence of a mechanism for training and advanced training of the relevant staff,
• attracting innovation-oriented companies to the cluster,
• creating the cluster’s production core of anchor enterprises,
• creating links between universities, business and government agencies,
• exchange of know-how and technical knowledge,
• focus on the provision of various services both inside and outside the cluster.

Based on the analysis of the activities of 15 Russian clusters, which include facilities for the production of bio- or nano-technological products [23], the authors formulated the below fundamental conditions for creating bionanotechnology clusters, assuming the presence of:
• large enterprises (the cluster’s production core),
• innovation infrastructure for small innovation entrepreneurship,
• networks of research centers,
• educational institutions training and retraining the staff,
• innovative transport and logistics system of interaction of all the cluster members,
• regional innovation, industrial, and cluster policy.

Thus, based on the study, a conceptual organizational model of an innovative international bionanotechnology cluster has been developed, which is shown in Fig. 1.
Also, for this model, a methodical approach to creating an innovative international bionanotechnology cluster has been developed, which includes 4 stages and is shown in Fig. 2. Each stage of building a cluster is a solution to a certain range of priority problems required for the transition to the next stage.

**Figure 1.** The Proposed Conceptual Organizational Model of the EAEU’s Innovative International Bionanotechnology Cluster. *Drawn up by the authors*
When arranging bionanotechnology clusters, it is important to consider the experience of existing ones and avoid factors hindering their successful creation and development. According to the authors, the factors hindering the successful creation and development of innovative international industrial clusters include:

- incorrectly chosen cluster specialization,
- increased attention to material infrastructure detrimentally of the innovation business values, focus on attracting strong companies, staff, and projects,
- priority development of technologies and research detrimentally of the economic goals of the business,
- building the cluster's innovation infrastructure based on unreliable forecast data,
- too low infrastructure adaptability,
- lack of foresight and long-term planning of cluster development,
- insufficient professional level of experts involved in the cluster,
- insufficient involvement of scientific and university centers in the cluster activity.

Herewith, in our opinion, the following should be attributed to the positive EAEU’s cluster formation patterns:

- choosing the cluster specialization based on understanding the path of future development of world markets and the local advantages and conditions,
- correlating the cluster's activities with the long-term strategies of the EAEU member states,
- creating a strong innovation cluster brand,
properly choosing an innovation company acting as the cluster core and anchor innovation companies,

- attracting investors,
- creating attractive and favorable conditions for the cluster participants.

Considering these regularities, the general bionanoindustry situation analysis, and global trends of the sixth wave of innovation, we believe that the bionanotechnology cluster model should be focused on new vectors of high-tech business development in the EAEU. The high-tech business development vectors in the new EAEU’s bionanoindustry cluster model formulated by the authors are shown in Fig. 3.

Since the bionanoindustry has arisen as a result of the convergence of new technologies at the junction of bio- and nanotechnologies, the main areas of long-term development of which are of a complex and interconnected nature (see Fig. 4), then to successfully develop a bionanotechnology cluster, a system of long-term effective forecasting and foresight in the field of bionanoindustry is requires, which is designed to perform the below key functions:

- creating a special infrastructure and methodology for long-term forecasting,
- strategic indicative and program planning,
- monitoring of processes in the field of science and technology,
- estimating the niche and global product market development trends,
- analyzing the business development models,
- informing and convergence in these areas.

The absence of own forecasting within clusters forces them to take a catch-up position in the development of new technologies, including on a global scale. The most adequate tool to arrange a system of long-term effective forecasting in the field of bionanoindustry is creating a foresight center within the bionanotechnology cluster structure.

The main difference between foresight and conventional forecasting is that the future is seen as a result of trends that have not yet been manifested. The foresight’s specifics are the combination of forecasting and insight, which allows using it as a specific tool for managing innovation development.
Methodical recommendations for creating a foresight center within the structure of bionanotechnology clusters and estimating its efficiency include the below stages and steps.

1. Formulating the mission, main activities, and tasks of the foresight center. The bionanotechnology cluster’s foresight center mission is arranging and performing research in the field of long-term forecasting and identifying priority areas of socio-economic, scientific and technological, and innovation development; creating and disseminating the foresight methodology and tools; facilitating the integration of the cluster into international and national research programs and projects.

The bionanotechnology cluster’s foresight center activities include creating and implementing the foresight projects; developing and disseminating the foresight methodology; consulting and training.

The main bionanotechnology cluster’s foresight center tasks include providing effective mechanisms for the implementation of international foresight projects; developing practical recommendations for the application of the foresight methodology; estimating the technological trends and development scenarios in the field of bionanotechnology; forming and developing competencies to perform research on the foresight methodology.

Figure 3. High-Tech Business Development Vectors in the New EAEU’s Bionanoindustry Cluster Model. Drawn up by the authors.
Specific foresight center tasks are strategic and technological forecasting, setting the bionanotechnology cluster development priorities; generating proposals for changing the cluster development program; choosing markets and ‘portfolios’ of basic cluster technologies; alignment of the bionanotechnology cluster development priorities with forecasts and strategies for the EAEU’s scientific and technological development.

2. Formulating the main foresight research stages. The main foresight research stages are [24]:
- creating a leadership group of a foresight project,
- defining the foresight research object and subject,
- creating major conditions,
- creating a subject map and expert panels, performing research and surveys,
- describing various future alternatives, trends, and scenarios,
- developing strategies, programs, plans, and ‘roadmaps’,
- institutionalizing and determining regular mechanisms for updating roadmaps, strategies, and other foresight research results.

3. Choosing the foresight methodology. The foresight methodology is diverse and includes both conventional and new expert techniques, including review and scanning of sources, expert panels, public panels, Delphi method, brainstorm, determining key technologies, mapping technologies, analyzing mutual impacts and global trends, SWOT analysis, development of the future, scenario planning, reverse scenario planning, simulation.

4. Considering the requirements for the elaboration of the foresight development programs in the EAEU, which is based on the below provisions: long-term scientific and technological forecast should
be integrated into the common EAEU’s economy strategic management system; choosing the foresight participants is of prime importance; the possibility of using the scientific and technological foresight results to modernize the EAEU countries’ economies.

5. Choosing promising scientific and technical research areas using foresight technologies and their further implementation, including the foresight tools.

6. To expand the involvement in the latest scientific and technological trends and the efficiency of research and development, obligatory interaction of the foresight center with the EAEU’s bionanotechnology platforms is required. We recommend the below technology platforms: EurasiaBio, Eurasian Biomedical Technology Platform, Photonics, Eurasian Agricultural Technology Platform, Eurasian Supercomputer Technology Platform, Environmental Development Technologies, Metallurgy Technologies and New Materials, and Eurasian LED Technology Platform.

7. Estimating the efficiency of the foresight center within the cluster. The internal effect of embedding a foresight center in the infrastructure of a bionanotechnology cluster may be confirmed by the below results:

- the priority cluster’s activities are determined using a justified scientific and methodological basis,
- scenarios for the development of individual bionanotechnology product markets by the cluster profile and marketing strategies for selling products on global and national markets are developed,
- programs for innovation (primarily, scientific and technological) cluster development are developed considering the forecasted demand and the risks of bionanotechnology product markets development,
- mechanisms for the transfer of scientific developments to large-scale production are chosen considering the prospects for the demand in certain markets for bionanoproducts and services (b2c) and technologies (b2b),
- the (scientific and technological) road maps for the bionanoeconomy sectors determined by the bionanotechnology cluster specialization areas are developed,
- the professional participation of the cluster organizations in the technological platform activities is ensured to identify the ‘breakthrough’ scientific and technological development areas in the field of the bionanotechnology cluster specialization [13].

The external effect of the bionanotechnology cluster’s foresight center activity is expressed for:

- the state through the implementation of scientific and technical policy manifested in technology platforms, sectoral strategies, programs for innovative development of GSEs, scenarios for the long-term development of the EAEU, country, regions, and cities,
- the state scientific centers through drawing up a plan for fundamental research, obtaining relevant research objectives and developments,
- scientific foundations and development institutions through participation in the determining and implementing the priorities of scientific and technological development, determining the subjects of joint research and development, supporting strategic initiatives,
- large businesses through identifying the present-day challenges and ‘windows’ of opportunities, developing innovative strategies and programs, drawing up the retooling plans,
- small and medium-sized businesses through understanding the priorities of scientific and technological development, participation in joint innovation projects,
- research and other universities through determining the relevant research objectives, developing modern educational programs, participation in joint research and development.

Thus, the efficiency of the recommendation for creating a foresight center within the EAEU’s innovative international bionanotechnology cluster is expressed in:

- identifying the most probable future changes in the scientific and technological, social and production, and export bionanoindustry potential through joint efforts of all the foresight process participants,
• determining the long-term strategies for the development of science, technology, and economy in individual bionanotechnology sectors,
• determining the priority cluster activities according to the global trends in the development of nano- and biotechnology,
• making the right choice of bionanotechnology markets,
• stimulating the bionanotechnology cluster development,
• weighted estimating the dynamics and structure of demand for the bionanotechnology cluster products,
• building an effective infrastructure for the transfer of scientific developments to large-scale production,
• forecasting risks and developing anti-crisis strategies for various scenarios of bionanotechnology market development.

The problems and issues raised in the authors’ previous and this work require further research, scientific study, and preparing recommendations and measures for the development of high-tech industry in the Eurasian Economic Union. The authors see the further research areas in scientific justification of creating the engineering infrastructure within innovative international bionanotechnology clusters, including the arrangement of engineering centers within them to provide various engineering services to small and medium-sized innovation enterprises forming the cluster, the performance of joint research and development, the acceleration of transferring technologies to large-scale production, and training staff qualified in bio-nano-oriented engineering, as well as such an important issue as improving the state cluster policy for the development of high-tech complexes with the participation of the Eurasian Economic Union member countries and other interested parties.

6. Conclusion
The high-tech industry development is a promising scientific area as part of solving an ambitious state task to ensure a scientific and technological breakthrough. One of the driving forces of this breakthrough may be a promising high-tech bionanoindustry based on the convergence of bio-, nano- and other technologies. Based on the research of the high-tech industry issues, the authors believe that creating innovative international bionanotechnology (industrial) clusters is an efficient methodical form of high-tech bionanoindustry development.

This conclusion is based on the below results of the study performed by the authors:
1. Based on the analysis of scientific, methodological, and practical experience in the field of clusters and cluster formation theory and the study of practical models of regional and international innovation clusters, the below results have been obtained:
• aspects to be considered by the methodology for the EAEU’s international cluster development have been formulated,
• based on the analysis of the Pushchino Biotechnological Innovative Territorial Cluster infrastructure model and the common regional innovation cluster model, the main specifics of the bionanotechnology cluster model have been formulated,
• based on the analysis of the activities of 15 Russian clusters including facilities for the production of bio- or nanotechnology products, the fundamental conditions for creating bionanotechnology clusters have been formulated.
2. A conceptual organizational model of the Eurasian Economic Union’s innovative international bionanotechnology cluster has been developed with the below results obtained:
• the conceptual organizational model of the EAEU’s innovative international bionanotechnology cluster,
• a methodical approach to creating (creating stages) an innovative international bionanotechnology cluster,
• the factors hindering the successful creation and development of innovative international industrial clusters,
• a list of positive patterns of clustering within the EAEU,
• a list of high-tech business development vectors in the new model of clustering the EAEU’s bionanoindustry.

3. Creating a foresight center within the bionanotechnology cluster structure to arrange efficient long-term forecasting for the bionanoindustry has been justified.

4. Methodical recommendations for creating a foresight center within the bionanotechnology cluster structure and estimating its efficiency have been developed.

5. Further research areas have been formulated:
• scientific justification of creating an engineering infrastructure within the innovative international bionanotechnology clusters, including the arrangement of engineering centers within them to provide various engineering services to small and medium-sized innovative enterprises forming the cluster, the performance of joint research and development, the acceleration of transferring technologies to large-scale production, and training staff qualified in bio-nano-oriented engineering;
• improving the state cluster policy for the development of high-tech complexes with the participation of the Eurasian Economic Union member countries and other interested parties.

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