MODELING OF REGIONAL ECONOMIC DEVELOPMENT BASED ON INNOVATIVE CLUSTERS

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Abstract

The subject of the research is improvement of methodological tools for modeling economic development based on the formation of innovative clusters of environmental management within the region economic space. The aim of the work is to develop an economic-mathematical model for the formation of innovative clusters, expanding the methodological potential of forecasting and planning territorial development. Special attention is paid to the peculiarities of innovative cluster development process, which determine the initial conditions of the problem of finding the optimal spatial location and long-term development of industrial production in the cluster. The problems of optimization of spatial distribution of new and development of existing industries in the process of implementation of the cluster initiative are considered, approaches to mathematical modeling of formation and development of innovative clusters are generalized. The features of the economic-mathematical model of the formation of innovative cluster of environmental management are identified. The problem of optimizing economic development for territory on the basis of innovation cluster are formulated.

Keywords: economic clustering, innovation clusters, environmental management, optimization of economic development, economic-mathematical model, territorial development, industrial policy, regional economy, old-industrial regions, resource-producing industries, inter-sectoral interaction.

JEL classification: O1, R58

1. Introduction

The solution of the tasks of economic development and modernization for regional old-industrial economic systems actualizes the task of the practical implementation of the model for perspective development of cluster initiatives in the framework of the innovation economy. In the framework of the study, the old industrial region is understood as a territory with a predominantly obsolete industrial base characterized by a low level of technological development. The main problem of this type of regions is overcapacity, represented by large and medium-sized enterprises with outdated equipment and technologies. Modernization of the economy of old industrial regions, as a rule, is also complicated by the presence of a complex of social, demographic and environmental problems.

The author's approach to analyzing the relationship of innovative clusters and sectoral specialization of the territory where they are located is based on identifying two main types of territorial economic systems with industrial, scientific and technical potential to create and develop innovative clusters. The first type includes the potential innovative clusters identified on the basis of the calculation of the localization factor for the production of “agglomeration” based on the existing high-tech industrial production within the territory. The second type of territorial systems selected by the author is formed by “conglomerates” of sectoral complexes uniting enterprises in related economic activities. For this type of territorial systems, the implementation of production technologies of previous technological structures is typical. Consideration of old industrial regions as one of the promising areas of cluster policy is due to the following factors: old industrial regions have a developed production infrastructure and fairly stable links between economic entities, and these territories have a strong industry specialization, characterized by a high proportion of the main branches of production.

2. Data and method

Cluster development model. The innovation cluster allows integrating both traditional (old-industrial) and resource-oriented sectors, as well as related innovative activities within the sixth technological order, within a single organizational environment. The formation of an innovation cluster, which is the "core" of multi-cluster, creates a scientific and technological base for the transformation of economic systems of old industrial regions (Napolskikh, 2017). Within the framework of the author's approach, it is possible to talk about the following areas of economic modernization: a change in the economic specialization and employment structure of the population of single-industry towns due to their inclusion in the formed industrial clusters; general transformation of the economic space of the regions within the framework of cluster policy, implying qualitative and quantitative changes in the structure of industrial production, renewal of fixed assets, growth of labor productivity.

It is proposed to highlight innovative environmental management clusters as an adequate model of economic modernization for most old-industrial regions. The formation of innovative clusters of environmental management is especially important for areas that do not have hydrocarbon resources and a developed industrial base. The formation of this type of cluster is based on the integration of related economic activities, based on the following technologies:

- technologies of resource-saving ("lean") industrial production;
- technologies of resource-saving processing of forest resources and minerals.
- technologies for sustainable forest management and reforestation;
- technologies for the production of organic food and efficient processing of agricultural products;
- veterinary and phytosanitary technologies to ensure the safety of crops and animals;
- technologies of "green energy" and intellectual energy saving;
- technologies for environmentally safe transportation and disposal of industrial wastes;
- technologies for the production of fuel and new energy sources based on organic raw materials.

Consequently, an innovative environmental management cluster is a territorial-production system integrated on the basis of innovative environmental management technologies, within which renewable resources of the territory are optimally used and a sustainable restoration of the natural environment is ensured (Napolskikh, 2014).

Features of the economic and mathematical model of clustering of the regional economy based on the formation of an innovative cluster of environmental management. Building an economic-mathematical model for optimizing the structure and size of production within a cluster increases the level of objectivity of the cluster development strategy (Gimadeeva, 2015). The practical application of the developed economic and mathematical model is considered on the basis of the application of modern mathematical methods for solving complex optimization problems (Lychkina, 2012; Starikov and Kuscheva, 2008) and the use of specialized software packages (Apatova, 2009; Afraimovich and Prilutsky, 2010), regional policy, which endogenous growth strategy utilizes (Papadaskalopoulos, A Nikolopoulos P., 2018), including the institutions and mechanisms of technology transfer (Kokkinou A., Ladias C., Papanis E., Dionysopoulou P. 2018).

The economic essence of the task of optimizing the structure and size of production within the cluster is in the following provisions:

- known limited amount of non-renewable natural resources of the territory and the maximum allowable use of renewable resources of the cluster;

the need to optimize the use of natural resources in the cluster within the framework of the concept of environmental management;

known current volumes of industrial production and promising indicators of its development;

known needs for raw materials and finished products of consumers belonging to other industry segments of cluster;

possibility of integrating production with other regions, the supply of cluster products to consumers located in region, other regions, as well as deliveries to the external market.

Also, as the determining factors of the formation of the economic-mathematical model, it is necessary to highlight:

integration within the framework of the model of main types of raw materials, materials and finished industrial products;

consideration of the production capabilities of the industrial enterprises of the cluster based on their availability of material, energy, labor and other types of resources;

inclusion in the model of sources for the development of cluster production capacities.

3. Analysis and Results

3.1. Statement of the task for optimizing the economic development of a territory based on the formation of innovative cluster of rational nature management.

Consider a innovative cluster of rational environmental management in the form of an ordered multi-structured regional economic system, which includes enterprises and final consumers of finished products (Korobov, 2010). The industry segments of the cluster are proposed to be considered separately, taking into account its relationship with other segments. Accordingly, we adopt the following conventions:

i – is the index of the type of natural resources extracted on the territory of the cluster, ;

i^t – is the index of the type of technological waste used as secondary raw materials and secondary fuel and energy resources both within the framework of the considered and other industry segments of the cluster, $i^t = \overline{1, n^t}\, \mathbf{i}^t = \overline{\mathbf{1}, \mathbf{n}}$;

j – is the index of the type of primary processed natural resources of a commercial type produced on the territory of a cluster, , also we introduce sub-indices for the primary processed natural resources of a commercial type in accordance with the territory of their supply:

$\mathbf{j}_c$ – deliveries to consumers within a cluster;

$\mathbf{j}_g$ – deliveries to consumers within the region;

$\mathbf{j}_e$ – deliveries to consumers in other regions and for export.

k^1 – is the index of the type of primary raw material natural resources produced on the territory of the cluster, and we also introduce sub-indices for raw natural resources in accordance with the territory of their supply:

k_c^1 – deliveries to consumers within a cluster;

k_g^1 – deliveries to consumers within the region;

k_e^1 – deliveries to consumers in other regions and for export.

k^2 – index of the type of secondary raw natural resources produced on the territory of the cluster, $k = \overline{1, r^2}$, also we introduce sub-indices for raw natural resources in accordance with the territory of their supply:

k_c^2 – deliveries to consumers within a cluster;

k_g^2 – deliveries to consumers within the region;

k_e^2 – deliveries to consumers in other regions and for export.

s^1 – the index of the type of finished industrial products produced by enterprises of the cluster from primary raw materials, $s = \overline{1, d^1}$,

s^2 – the index of the type of finished industrial products produced by enterprises of the cluster from primary and secondary type raw materials, ;

w – the index of low-grade natural resources used both within the framework of the surveyed and within the rest of the industry segments of the cluster within the framework of technological processes $[(w]]_1 1$), and also as side fuel and energy resources (w_2).

We also introduce the following designations of the initial information for the construction of an economic-mathematical model:

A^{max} - maximum allowable use of natural resources on the territory of the cluster;

a_i – the volume of natural resources used by their types;

B_k – the total production capacity of the industrial enterprises of the cluster: k^1 - production using primary raw materials, k^2 – production using primary and secondary raw materials;

$Q_{k_c}; Q_{j_c}$ – the total needs of consumers within the cluster by types of raw natural resources and primary processed commodity resources;

$\underline{Q_{k_g}}; \underline{Q_{j_g}}$ – commitments on the supply of raw natural resources and raw materials processed raw materials within the region;

$\underline{Q_{k_e}}; \underline{Q_{j_e}}$ – for the supply of raw natural resources and primary processed commodity resources to other regions and to the external market;

$Q_{k_c^1 s^1}; Q_{k_c^2 s^2}$ – internal needs of cluster consumers for finished industrial products.

We also introduce the following notation for the main sought-for variables in the framework of the economic-mathematical model:

$x_{j_c i}$ – the production of the *j*-th type of primary processed natural resources of the commodity type for the *i*-th type of natural resources mined in the cluster for the internal needs of its industry segments;

$x_{j_g i}$ – the production of the *j*-th type of primary natural resources of the commodity type for the *i*-th type of natural resources extracted in the territory of the cluster to meet the needs of the region of its location;

$x_{j_e i}$ – the production of the *j*-th type of primary processed natural resources of the commodity type for the *i*-th type of natural resources mined on the territory of the cluster for supply to other regions of the country and to foreign markets;

$x_{k_c^1 i s^1}$ – the volume of production of the *k*-th type of raw natural resources from the *i*-th type of natural resources extracted on the territory of the cluster for processing at enterprises with the aim of producing s^1--th industrial products produced by the cluster enterprises from primary raw materials;

$x_{k_g^1 i}$ – the volume of production of the *k*-th type of raw natural resources from the *i*-th type of natural resources extracted on the territory of the cluster to meet the needs of the region where the cluster is located;

$x_{k_e^1 i}$ - the volume of production of the *k*-th type of raw natural resources from the *i*-th type of natural resources extracted on the territory of the cluster for deliveries to other regions of the country and to foreign markets;

$x_{k_c^2 i s^2}$ – the volume of production of the *k*-th type of raw natural resources from the *i*-th type of natural resources extracted on the territory of the cluster for processing at enterprises for the production of s^2-th type of industrial products produced by the enterprises of the cluster as from primary, and secondary raw materials;

$x_{k_c^2 i^t s^2}$ – the volume of formation of the k^t-th type of technological waste used as secondary raw materials, and accordingly its industrial processing at the k^2 -th production of the cluster with the aim of producing the s^2-th type of finished product;

$x_{w_1 is^2}$ – the volume of production of the w-th type of low-grade natural resources from the i-th type of natural resources extracted on the territory of the cluster with the purpose of their industrial processing in the production of the s^2-th type of finished products;

$x_{w_2 i}$ – the volume of production of the w-th type of low-grade natural resources from the i-th type mined in the cluster to be used as secondary fuel and energy resources;

x_{i^t} – the volume of formation of the i-th type of technological waste used as side fuel and energy resources.

Thus, the formulated equation of the objective function F (x), describing the total economic income for the whole will have the following form:

$$F(\mathrm{x}) = \sum_{j_c,i}^{m,n} x_{j_c i}\, y_{j_c i} + \sum_{j_g,i}^{m,n} x_{j_g i} y_{j_g i} + \sum_{j_e,i}^{m,n} x_{j_e i} y_{j_e i} + \sum_{k_c^1,i,s^1}^{r^1,n,d^1} x_{k_c^1\, is^1} y_{k_c^1\, is^1} + \sum_{k_g^1,i}^{r^1,n} x_{k_g^1 i} y_{k_g^1 i} + \sum_{k_e^1,i}^{r^1,n} x_{k_e^1 i} y_{k_e^1 i} + \sum_{k_c^2,i,s^2}^{r^2,n,d^2} x_{k_c^2 is^2} y_{k_c^2 is^2} + \sum_{k_c^2,i^t,s^2}^{r^2,n^t,d^2} x_{k_c^2 i^t s^2} y_{k_c^2 i^t s^2} + \sum_{i,s^2}^{n,d^2} x_{w_1 is^2} y_{w_1 is^2} + \sum_{i=1}^{n} x_{w_2 i} y_{w_2 i} + \sum_{i^t=1}^{n^t} \mathrm{x}_{i^t} \mathrm{y}_{i^t} \rightarrow \max \quad (1)$$

where y – is the total economic income from the use, production and sale of one conventional unit of enlarged types of raw materials, materials and products of the cluster.

3.2. Restrictions of the values of the desired variables.

First of all, the condition of no negativity of values, respectively, x≥0, extends to all the required variables x. We will also consider the limitations caused by the economic characteristics of the location and development of production within the cluster of rational environmental management.

We introduce into the model the restrictive conditions for the cluster resuscitation industries, due to their characteristics and requirements for environmental management. The restriction based on the total maximum allowable total use of natural resources is as follows:

$$\sum_{j_c,i}^{m,n} x_{j_c i} + \sum_{j_g,i}^{m,n} x_{j_g i} + \sum_{j_e,i}^{m,n} x_{j_e i} + \sum_{k_c^1,i,s^1}^{r^1,n,d^1} x_{k_c^1\, is^1} + \sum_{k_g^1,i}^{r^1,n} x_{k_g^1 i} + \sum_{k_e^1,i}^{r^1,n} x_{k_e^1 i} + \sum_{k_c^2,i,s^2}^{r^2,n,d^2} x_{k_c^2 is^2} + \sum_{i,s^2}^{n,d^2} x_{\mathrm{w}_1 is^2} + \sum_{i=1}^{n} x_{w_2 i} \leq A^{max} \quad (2)$$

Therefore, when included in the economic-mathematical model of the planned use of natural resources within the framework of the cluster development policy (V1) compared with the already achieved volumes (A0), the formulated restriction will take the following form:

$$\sum_{j_c,i}^{m,n} x_{j_c i} + \sum_{j_g,i}^{m,n} x_{j_g i} + \sum_{j_e,i}^{m,n} x_{j_e i} + \sum_{k_c^1,i,s^1}^{r^1,n,d^1} x_{k_c^1\, is^1} + \sum_{k_g^1,i}^{r^1,n} x_{k_g^1 i} + \sum_{k_e^1,i}^{r^1,n} x_{k_e^1 i} + \sum_{k_c^2,i,s^2}^{r^2,n,d^2} x_{k_c^2 is^2} + \sum_{i,s^2}^{n,d^2} x_{w_1 is^2} + \sum_{i=1}^{n} x_{w_2 i} - V_1 = A_0 \quad (3)$$

Considering the cluster of rational nature management, it is necessary to introduce restrictions on the use in the production of secondary raw materials. Accordingly, the restrictive condition for the formation of secondary raw materials and its use in the industry segments of the cluster along with the primary raw materials for the production of finished products (s2) has the following form:

$$\sum_{j_c,i}^{m,n} u_{k^2i}x_{j_ci} + \sum_{j_g,i}^{m,n} u_{k^2i}x_{j_gi} + \sum_{j_e,i}^{m,n} u_{k^2i}x_{j_ei} + \sum_{k_c^1,i,s^1}^{r^1,n,d^1} u_{k^2i}x_{k_c^1\,is^1} + \sum_{k_g^1,i}^{r^1,n} u_{k^2i}x_{k_g^1i} + \sum_{k_e^1,i}^{r^1,n} u_{k^2i}x_{k_e^1i} + \sum_{k_c^2,i,s^2}^{r^2,n,d^2} u_{k^2i}x_{k_c^2is^2} + \sum_{i,s^2}^{n,d^2} u_{k^2i}x_{w_1is^2} + \sum_{i=1}^{n} u_{k^2i}x_{w_2i} - \sum_{k_c^2,i^t,s^2}^{r^2,n^t,d^2} x_{k_c^2i^ts^2} - \sum_{i^t=1}^{n^t} \mathrm{x}_{i^t} = 0 \quad (4)$$

where u_{k^2i} – the formation factor when using the *i*-th type of natural resources of the k^2-th type of waste, which can be used as secondary raw materials for the manufacture of finished products at cluster enterprises.

We will also introduce into the model limitations that characterize the conditions for the provision of raw materials to cluster enterprises using primary raw materials, taking into account the expansion of existing and creation of new industries within the cluster policy:

where: $B_{k^1}^{min}$ $\mathrm{B}_{\mathrm{k}}^{\mathrm{min}}$– the minimum capacities of typical production (workshops, lines, units, etc.), characterized by the volumes of processing of primary raw materials;

z_{k^1} – the variables sought in the framework of the economic-mathematical model, which are multiplicity coefficients; z_{k^1}=0,1,2,3 …

When the planned volumes of industrial processing of natural resources are included in the economic-mathematical model within the framework of the cluster development policy (V_{k^1}) compared to the already achieved processing volumes ($M_{k^1}^0$), the stated restriction will take the following form:

$$\sum_{k_c^1,i,s^1}^{r^1,n,d^1} x_{k_c^1\,is^1} - V_{k^1} = M_{k^1}^0\,;\, k^1 = \overline{1,r^1} \quad (7)$$

We will also introduce restrictions into the model that characterize the conditions for the provision of raw materials to enterprises that use secondary raw materials obtained in the course of industrial processing, taking into account the expansion of existing and creation of new industries:

$$\sum_{k_c^1,\mathrm{i},\mathrm{s}^1}^{\mathrm{r}^1,\mathrm{n},\mathrm{d}^1} \mathrm{u}_{k^2k^1}x_{k_c^1\,is^1} - \sum_{k_c^2,\mathrm{i},\mathrm{s}^2}^{\mathrm{r}^2,\mathrm{n},\mathrm{d}^2} x_{k_c^2is^2} - \sum_{\mathrm{i}^t=1}^{\mathrm{n}^t} \mathrm{x}_{\mathrm{i}^t} = 0\,;\; k^2 = \overline{1,r^2} \quad (8)$$

where: $u_{k^2k^1}$ – the coefficient of formation in the course of industrial processing of primary raw materials of k^2-type of waste, which can be used as secondary raw materials for the manufacture of finished products at cluster enterprises.

Let us introduce restrictions into the model, which characterize the conditions for the provision of cluster enterprises with raw materials using primary and secondary raw materials, taking into account the expansion of existing and creation of new productions within the cluster policy:

$$\sum_{k_c^2,i,s^2}^{r^2,n,d^2} x_{k_c^2is^2} + \sum_{k_c^2,i,s^2}^{r^2,n,d^2} \mu_{k^2k^1}x_{k_c^2is^2} \le B_{k^2}\,;\, k^2 = \overline{1,r^2} \quad (9)$$

$$\sum_{k_c^2,i,s^2}^{r^2,n,d^2} x_{k_c^2is^2} + \sum_{k_c^2,i,s^2}^{r^2,n,d^2} \mu_{k^2k^1}x_{k_c^2is^2} - B_{k^2}^{min}z_{k^2} \le 0;\, k^2 = \overline{1,r^2} \quad (10)$$

where: $\mu_{k^2k^1}$ – the coefficient of interchangeability of primary raw materials secondary.

$B_{k^2}^{min}$ – the minimum capacities of typical production (workshops, lines, units, etc.), characterized by the volume of processing of secondary raw materials;

z_{k^2} – the variables sought in the framework of the economic-mathematical model, which are multiplicity coefficients; z_{k^1}=0,1,2,3 …

When the planned volumes of industrial processing of natural resources are included in the economic-mathematical model within the framework of the cluster development policy (V_{k^2})

compared to the already achieved processing volumes ($M^0_{k^2}$), the stated restriction will take the following form:

$$\sum_{k_c^2,i,s^2}^{r^2,n,d^2} x_{k_c^2 is^2} + \sum_{k_c^2,i,s^2}^{r^2,n,d^2} \mu_{k^2k^1} x_{k_c^2 is^2} - V_{k^2} = M^0_{k^2}\ ;k^2 = \overline{1,r^2} (11)$$

Next, we consider the restrictive conditions of the economic-mathematical model, due to the internal needs of the cluster and the delivery obligations:

the total needs of consumers in a multicultural cluster for the primary processed commodity resources:

$$\sum_{j_c,i}^{m,n} x_{j_c i} = Q_{j_c};\ j = \overline{1,m}\ (12)$$

total consumer needs in a cluster for natural resources:

$$\sum_{k_c,i}^{r,n} x_{k_c i} = Q_{k_c};\ k = \overline{1,r}\ (13)$$

obligations for the supply of primary processed commodity resources within the region:

$$\sum_{j_g,i}^{m,n} x_{j_g i} - Q_{j_c} \geq \underline{Q_{j_g}};\ j = \overline{1,m}\ (14)$$

obligations for the supply of raw natural resources within the region:

$$\sum_{k_g,i}^{r,n} x_{k_g i} - Q_{k_c} \geq \underline{Q_{k_g}}\ ;\ k = \overline{1,r}\ (15)$$

commitments on the supply of primary processed commodity resources to other regions and to the external market:

$$\sum_{j_e,i}^{m,n} x_{j_e i} - Q_{j_c} - \underline{Q_{j_g}} \geq \underline{Q_{j_e}}\ ;\ j = \overline{1,m}\ (16)$$

commitments on the supply of raw natural resources to other regions and to the external market:

$$\sum_{k_e,i}^{r,n} x_{k_e i} - Q_{k_c} - \underline{Q_{k_g}} \geq \underline{Q_{k_e}}\ ;\ k = \overline{1,r}\ (17)$$

total domestic needs of cluster consumers in finished industrial products made from primary raw materials:

$$\sum_{k_c^1,i,s^1}^{r^1,n,d^1} x_{k_c^1 is^1} \geq Q_{k_c^1 s^1}\ ;k = \overline{1,r}\ (18)$$

total domestic needs of cluster consumers in finished industrial products made from primary raw materials:

$$\sum_{k_c^2,i,s^2}^{r^2,n,d^2} x_{k_c^2 is^2} + \sum_{k_c^2,i,s^2}^{r^2,n,d^2} \mu_{k^2k^1} x_{k_c^2 is^2} \geqslant Q_{k_c^2 s^2}\ ;k = \overline{1,r}\ (19)$$

Also, in the framework of the economic-mathematical model, restrictions were introduced that characterize the objective economic possibilities for the development of a cluster. Restrictive conditions on the availability of internal (μ) and external (φ) investment resources for the development of production within a cluster will be as follows:

$$\delta_1 V_1 + \sum_{k^1=1}^{r^1} \delta_{k^1} V_{k^1} + \sum_{k^2=1}^{r^2} \delta_{k^2} V_{k^2} - \varphi = \mu\ (20)$$

where: δ – the specific investment rate for the development of the functioning and creation of new productions of the cluster, in rubles per unit of power of the productive forces.

Based on this restrictive condition, restrictions on other factors of cluster development (labor resources, etc.) can be included in the economic-mathematical model.

4. Conclusion.

Thus, the practical application of the developed economic-mathematical model is possible with the help of specialized application packages. Economic-mathematical modeling of cluster development processes complements the existing methodological tools of cluster policy, reducing the influence of subjective factors in solving the problems of spatial development of the productive forces. The results obtained in the course of the study are aimed at expanding the methodological tools of representatives of the scientific and educational community, state and local government bodies, and institutions of territorial and industrial development.

The results obtained in the framework of the study allowed us to expand the methodological basis of cluster policy, while in the modern practice of implementing cluster policy, the traditional approach remains with spatial localization of the formed clusters (Markov, 2015; Naydenov, Spiryagin and Novokshonova, 2015)

Within the framework of this approach, the territory of cluster development processes, the implementation of multiplicative effects and innovative transformation of the economy often coincides by default with the existing administrative boundaries of the constituent entities and municipalities (Gimadeeva, 2015; Chernyakina, 2015). It should be noted that the possibilities for implementing the proposed model for old industrial regions are limited by market conditions and the presence of a complex of political and social factors. In particular, low susceptibility to managerial innovation can be identified; the inertia of the historically established industrial specialization of the territory in the division of labor; as well as the narrow localization of markets for products, in turn, has a low level of technology.

Consequently, today, for the economic thought, the development of methods for modeling and visualizing the development processes of clusters within the economic space of the regions remains relevant. The solution of this scientific task involves the further study of the transformation processes of the internal structure of the economic space of a region under the influence of clustering processes.

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