

Methodological aspects of ontogenesis of regional industrial clusters

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Abstract — The paper considers the problem of clusterisation in the economic space of regions of Russia and the world. The algorithm of the methodology of identification of the cluster ontogenesis stage is developed in the paper. The research by the example of titanium, chemical and pharmaceutical clusters of Sverdlovsk region showed a decrease in the value of geographical concentration with a simultaneous internationalization of economic activities of the cluster.

Keywords — cluster; cluster ontogenesis stage; problems of clusterisation; innovative potential; economic space

I. INTRODUCTION

The organization of economic space as an effective environment of socio-economic processes is a topical issue of the modern concept of regional development. The main purpose of this process is to increase the efficiency of the use of specific areas capability by upgrading the organizational forms of activity of economic subjects, which are formed at the moment. The realization of the goal implies the search of the scientific justification tools of the applicability of the use of the specific forms of economic organization, based on territorial-sectoral specifics and hierarchical levels of the formed structures.

Analysis of strategic and conceptual documents of the federal and regional level, covering the processes of socio-economic development of the Russian economy enables one to identify the specific organizational form of activity of economic subjects, which is named as the cluster. In particular, the cluster approach is presented in the Forecast of the long-term socio-economic development of the Russian Federation for the period up to 2030¹. In this document, the cluster is considered as a tool for regional development, ensuring the formation of points of growth in a particular area.

A similar approach is considered in the concept of long-term socio-economic development of the Russian Federation for the period until 2020², where clusters are represented as specific institutional mechanisms for ensuring the growth of competitiveness of the domestic economy and the transition to

a new technological platform (information, bio - and nanotechnology).

This concept has two stages the country's transition to an innovative path of development.

Stage 1 (2008-2012) – increase the competitive advantage of industries that are typical for the Russian economy. One of the bases of economic modernization put forward the formation of high-tech industries through the creation of regional clusters in the regions of the Russian Federation. In the framework of implementation of the first stage, the Ministry of economic development of the Russian Federation had selected 25 of pilot innovative territorial clusters, the activity of which is supported by the government. The formed clusters can be considered as "growth points" in the complementation of the second stage.

Stage 2 (2013-2020) – creation the conditions for a strong impulse in the industrial development of the country, which is accompanied by the transition to new technologies and innovation and the creation of industrial clusters.

The main advantage of the cluster approach of regional development is the availability of a synergistic, multiplicative effect, thereby increasing the overall efficiency of production activities. It is necessary to emphasize the importance and urgency of economic and statistical study of the processes of economy clustering and territorial clusters.

A lot of attention is paid to the problems of economic substantiation of creation of clusters and economic analysis of their activities in the scientific literature in recent years.

Problems of clusterization in the economic space of regions of Russia and in the world is the object of many scientific studies, including the writings of G. Arbia, G. Espa, D. Giuliani, A. Mazzitelli [1], Y. Arimoto, K. Nakajima, T. Okazaki [2], E. Barbieri, M.R.D. Tommaso, S. Bonnini [4], A.A. Battalova, A.M. Battalov [5], S.V. Bularsky, S.A. Bularskaya, A.O. Sinitsyn [6-7], S.A. Dikunov, A.S. Brovko, and M.S. Dikunova [8], A.Yu. Fedotova [9], E.V. Gubanova [10], T. Hashino, K. Otsuka [11], E.I. Kostyukova, A.N. Bobryshev, K.G. Mamedova [13], O.L. Ksenofontova, E.A. Abramova [14], E.S. Kutsenko [15], D. Libaers, M. Meyer [16], R. Lu, M. Ruan [17], F.B. Mahmadiyev, N.S. Holowa [18], L.S. Markov, M.A. Yagolnitsker [20] [31], A.S.

¹ Forecast of the long-term socio-economic development of the Russian Federation for the period till 2030

² Concept of long-term socio-economic development of the Russian Federation for the period till 2020

Mikhailov [21-22], F.B. Menshenina, N.S. Kapustina [23], E.B. Naidanova, N.M. Polyanskaya [24], E.S. Ogorodnikova [26], M. Porter [28], G.A. Yasheva [32-33] et al.

Cluster policy exists in both developed and developing countries, varies depending on the composition of participants, structure and types of products and services, the characteristics of the location as well as the level and the stage of their development. From the analysis of cluster policy in foreign countries, one can conclude that it is necessary to implement a "mixed" model of cluster policy, which is able to link the interests of the state and business on the basis of existing or developing infrastructure and cooperative ties [27].

The increasing popularity of clusters is reflected in the growing number of policies and initiatives supporting them. The analyses carried out so far indicate that clusters are drivers of competitiveness and innovation, of economic growth and jobs [25].

The traditional cluster theory of economic development defines the cluster as a mono-branch formation, localized within a certain territory. The network nature of the economy and the development of information and computer technologies have had an impact on the formation and development of clusters: the evolution of inter-firm links from territorial production complexes to the formation of international industrial clusters is taking place.

Still the unified approach to the assessment of the clustering of the economy to date does not exist.

The aim of this study was the testing of the approach to the identification of industrial cluster formations from the point of ontogeny cluster, characterizing the process of its formation and evolution, primarily from a structural point of view.

II. MATERIAL AND METHODS

Popularization of the cluster approach in developed economies has led to the active development of the ideas of M. Porter. The concept of "cluster – eng.", meaning "clot", "bunch (grapes)", "cluster (stars)", in relation to industries and companies was introduced into scientific circulation by the American economist M. Porter as far back as 1990. Its concept is a rhombus of national competitive advantages, which is best known among all studies on national and regional competitiveness [28].

In the world practice, there has not yet been a single cluster theory; there are many definitions of the concept of cluster, but there is no generally accepted classification of clusters and a unified approach to the study of cluster structures. Therefore, in these conditions, the continuation of system research in the field of conceptual apparatus formation and the basic conceptual provisions of the cluster concept acquires particular urgency.

In order to develop the theoretical foundations of the cluster for the development and implementation of effective cluster strategies, taking into account the accumulated theoretical basis for the study of clusters, the conceptual apparatus is refined.

The cluster, in the author's opinion, implies the network organization of complementary enterprises and organizations, interconnected by cooperation relations (including specialized suppliers, services, and producers and buyers), united around one or several research and educational centers that are linked by partnership relations with local institutions and state and regional government with the aim of achieving a synergetic effect that ensures the growth of competitiveness Enterprises, regions and the national economy.

The following indications of an industrial cluster can be singled out: localization and agglomeration of enterprises, organizations and public institutions united by horizontal and vertical links; complementarity of subjects; production of a "key" product; the presence of relations of competition and cooperation; achievement of a systemic economic effect (profitability above the industry average); development of informal relations and cooperation between the cluster entities, as well as partnerships between them and regional government bodies; unified infrastructure and institutional environment; association of enterprises around one or several scientific and educational centers.

At the same time, in the author's opinion, the sign of geographic or territorial localization of enterprises, allocated by many researchers at the present stage, can be excluded or not be the main one due to the intensive development of remote information and communication technologies.

The generalized analysis of scientific sources showed that nowadays, the most important aspect of the cluster formation researches is studying the objective economic prerequisites for their establishment as well as their initiative formation in the regions of Russia, which provides an integrated assessment of innovative potential of the territory, the development level of which affects the level of cluster initiatives and determines the degree of development of cluster groups in the region.

The study of a number of scientific publications, devoted to the formation and development of clusters, makes it possible to conclude that the majority of them are mainly limited to the level of a morphological description that allows one to distinguish only general features of the object of research and to classify and determine the elements [12]. Despite the fact that clusters as a specific form of economic management have been designated since the middle of the 19th century and only at the end of the 20th century, when the works of M. Porter were published, it became possible to talk about the formation of the clusters theory that allowed one to go beyond the empirical cognition to theoretical generalization. The researchers distinguish the following features that allow isolating clusters among other objects of economic space:

- Geographical proximity of cluster members;
- The composition of the participants of the cluster, which makes it possible to create a "critical mass";
- The existence of active links and interactions between the participants of the clusters.

World practice shows that in the last two decades the process of cluster formation has been quite active. In general,

according to experts, up to now, about 50% of the economies of the world's leading countries are clustered. The leaders in clustering are the USA (380 clusters); Italy (206 clusters); Great Britain (168 clusters); India (106 clusters); France (96 clusters); Denmark (34 clusters); Germany (32 clusters); the Netherlands (20 clusters) [19].

The process of forming clusters is also actively going on in Southeast Asia and China, in particular, in Singapore (in the field of petrochemistry), in Japan (automobile industry) and in other countries. In China, today there are more than 60 special zones-clusters, in which there are about 30 thousand firms with a staff of 3.5 million people. Moreover, their sales level is about \$ 200 billion a year [30].

Increasing competitiveness through cluster initiatives is becoming a basic element of development strategies for the vast majority of countries. An analysis of more than 500 cluster initiatives, implemented in the last 10 years in 20 countries, shows that the high competitiveness of these countries is based on the strong positions of individual clusters - the locomotives of competitiveness [30].

The large-scale analysis of information about 700 clusters in different countries showed that in 61% of the cases, the clusters were concentrated in the border of a city or metropolis. In 20% they are located on the territory within the borders of one region (state) and a substantially smaller part of the clusters was in a group of regions, countries or at the border between regions and countries. Another research, which was based on the analysis of 240 projects on the development of clusters, showed that in 60% of cases the projects covered clusters, the majority of participants of which were located on the territory with the radius of the hour-long journey [23].

According to the researches, clusters may consist of companies producing final goods and services generally exported outside the region, systems of suppliers of components, equipment, specialized services and professional educational institutions, research institutes and other organizations. The results of the analysis of 280 clusters shows that in 42% of cases clusters consisted of less than 100 companies, in 14 % - from 100 to 200 companies, in 10 % - from 300 to 400 companies, in 25% - of more than 600 firms. For example, in the textile cluster of Prato, Italy, more than 9,000 companies have been allocated [23].

In terms of functional description of the cluster as an object of scientific knowledge, the majority of studies are focused on two directions: the first, which is fairly widespread, considers the impact of clusters on the economy of the territory. The second direction, the researches on which are quite rare, considers the effects for individual enterprises as the elements of the cluster.

The researches aimed to study the role of clusters in economic development and productivity of the economy of the territories use the evaluation of relationship between GDP per capita and Integral Clustered Index, showing the level of development of clusters, as the key efficiency parameter (Fig. 1).

Practice shows that clusters are often created in Russia in certain sectors, development of which is a priority at the moment, and on the principle of "top-down" - regardless of whether it is an advantage to participants or not. Such national measures result in formal joint ventures, which are in fact independent of each other, without common goals, objectives and projects. Moreover, association of such enterprises in the cluster can hinder their activities, since there are no established mechanisms and modes of interaction, cooperation and coordination of resources.

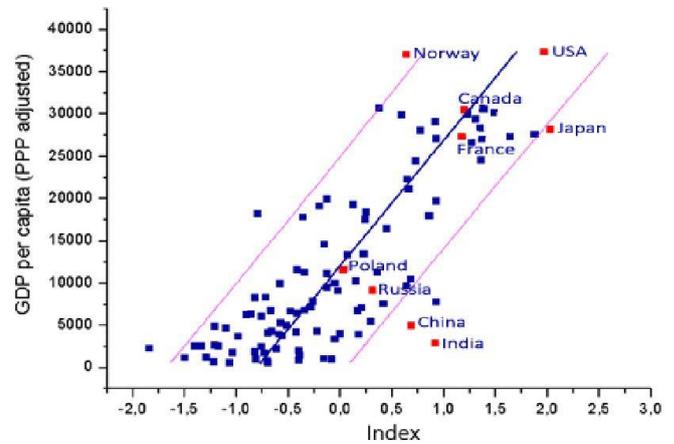


Fig. 1 The relationship between selective Integrated index and GDP (GRP) per capita [29]

At the same time, there are also some business combinations, institutions, naturally formed for mutual benefit, for effective interaction, which are not formally called clusters, but that really need to integrate their resources, knowledge, and they really need to receive government support. The difficulty of the cluster policy is to identify such clusters and reasonableness of their support [3].

One of the most actual instrument, used by the European Institutions for encouraging and supporting at the same time the entrepreneurs, is the promotion of clusters through participation to European calls for obtaining the necessary funds for industrial development of their SMSs and regions where they are located. The mentioned funds are dedicated more often to those clusters, which were in advance evaluated by an accredited institution. As it is known for the moment, there is only a unique institution in charge with this work, namely the European Secretariat for Cluster Analysis (ESCA) which uses a set of indicators (Fig. 2). On its basis, the quality of cluster management is eventually certified, after obtaining the "gold label" (there are actually three phases of evaluation, that include also the bronze and silver labels besides the gold one - depending on the development level of cluster organization). The use, at an European level, of cluster benchmarking has become more and more necessary, in the context of internationalization and of the tough competition that clusters have to face [25].

Presented indicators should be used as the basis for the formation of a cluster management company as key indicators

of its effectiveness and should be taken into account in the processes of cluster formation.

In the author's opinion, one of the important directions, but nevertheless insufficiently elaborated in the modern science of the cluster research, is to describe the ontogenesis of a cluster, characterizing the processes of its formation and evolution, primarily from a structural point of view.

<i>Structure of the cluster</i>	Age of the cluster organisation (<i>here and hereafter as CO</i>)
	Legal form of the CO
	Nature of the cluster: driving forces
	Nature of the cluster: degree of specialisation
	Composition of the cluster participants (<i>here and hereafter as CP's</i>) (Committed participants)
	Geographical concentration of the CP's (Committed participants)
	Utilisation of regional growth potential
	International participants of the cluster
	Nature of cooperation between CP's
	<i>Cluster management and governance / Strategy of the cluster organisation</i>
Number of per employee (full-time equivalents) of the CO	
Human resource competences and development in the CO	
Strategic planning and implementation processes	
Thematic and geographical priorities of the cluster strategy	
<i>Financing of the cluster management</i>	Repartition of the different financial sources (public funding, chargeable services, membership fees and other private sources) in the total budget of the CO in relation to the age of the cluster
	Financial sustainability of the CO
<i>Services provided by the cluster organisation (spectrum and intensity)</i>	Acquisition of third party funding
	Collaborative technology development, technology transfer or R&D without third party funding
	Information, matchmaking and exchange of experience among participants
	Development of human resources
	Development of entrepreneurship
	Matchmaking and networking with external partners / promotion of cluster location
<i>Achievements and recognition of the cluster organisation</i>	Internationalisation of CP's
	Number of external cooperation requests received by the CO
	Institutional origin of external cooperation requests
	Geographical origin of external cooperation requests
	Characteristics of cooperation with other international clusters
	Visibility in the press
	Impact of the work of the CO on R&D activities of the CP's
	Impact of the work of the CO on business activities of the CP's
	Impact of the business-oriented services of the CO on SME participants
	Degree of internationalisation of CP's
Impact of the work of the CO on international activities of the CP's	

Fig. 2 Overview of clusters benchmarking indicators used by ESCA³

In particular, determining the cluster is concentrated on a certain territory, a group of related companies, infrastructure, research organizations, et al. The author is not able to answer the question at which moment the described set of objects obtained new features missing from it disparate elements. And other questions are at which moment "externalities" have emerged and what they are; whether the cluster is an intermediate stage in the formation of structures of a higher level. The answer to these questions becomes the description of the ontogenesis of the cluster.

With the aim of solving the above-mentioned issues, let us propose a methodology to identify "externalities" in the formation of clusters, which is based on the provisions of the cluster theory that the companies, which are included in the cluster, receive greater impact of activities compared with the

industry average. Thus, cluster formation can be determined based on the calculation of the indicators of the cluster group importance in the region. Consequently, the unidirectional change in efficiency indicators of the enterprises included in the cluster group and indicators of the cluster group importance in the region will allow monitoring the stage of the ontogenesis of the cluster.

In fig. 3 and in table 1, the algorithm and the indicators of the developed methodology of identification of the cluster ontogenesis stage are presented.

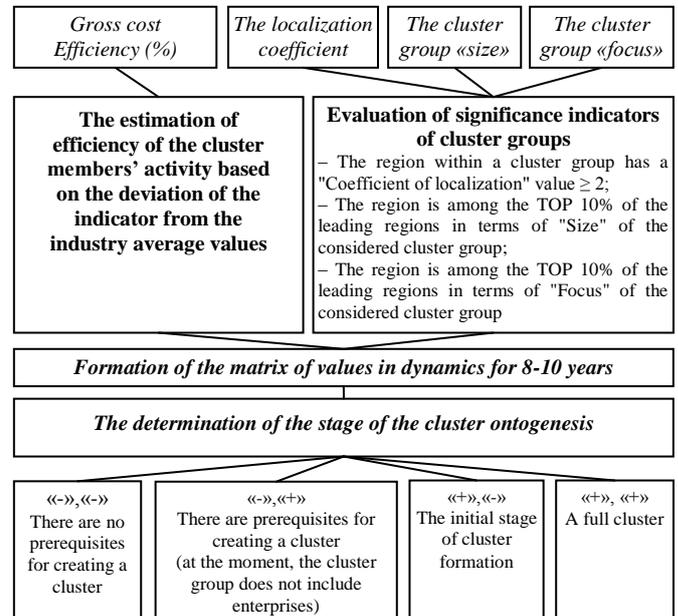


Fig. 3 The algorithm of the methodology of identification of the cluster ontogenesis stage⁴

TABLE I. THE INDICATORS OF THE METHODOLOGY OF IDENTIFICATION OF THE CLUSTER ONTOGENESIS STAGE

Indicator	Calculation of the indicator	Formula decoding
The main indicators of the significance of the cluster groups [15]		
<i>The localization coefficient</i>	$LQ = \frac{Inc_{ig}}{Inc_g} / \frac{Inc_i}{Inc}$	<i>LQ</i> – «the localization coefficient» <i>Inc_{ig}</i> – the volume of production in industry <i>i</i> of region <i>g</i> <i>Inc_g</i> – total production in region <i>g</i> <i>Inc_i</i> – the volume of production in industry <i>i</i> in Russian Federation <i>Inc</i> – Total production in Russian Federation
<i>The cluster group «size»</i>	$Size = Inc_{ig} / Inc_i$	<i>Size</i> – «the size» of cluster group <i>i</i> <i>Inc_{ig}</i> – the volume of production in cluster group <i>i</i> in region <i>g</i> <i>Inc_i</i> – the volume of production in cluster group <i>i</i> in Russian Federation
<i>The cluster group «focus»</i>	$Focus = Inc_{ig} / Inc_g$	<i>Focus</i> – «the focus» of cluster group <i>i</i> <i>Inc_{ig}</i> – the volume of production in cluster group <i>i</i> in region <i>g</i> <i>Inc_g</i> – the volume of production in region <i>g</i> .
The efficiency indicators of the cluster members activity		
<i>Gross cost efficiency (%)</i>	$P = Pr / C$	<i>P</i> – gross cost efficiency <i>Pr</i> – gross profit <i>C</i> – costs

³ Compiled by the author on the basis of ESCA, www.cluster-analysis.org

⁴ Compiled by the author

III. RESULTS

For the purpose of approbation of the proposed methodological apparatus, the author conducted the research by the example of titanium, chemical and pharmaceutical clusters of Sverdlovsk region. The results of the analysis are presented in tables 2 and 3.

TABLE II. DEVIATION FROM THE INDUSTRY AVERAGE INDICATOR VALUE OF PROFITABILITY OF PRODUCTION FOR THE ENTERPRISES OF THE CLUSTER %⁵

Year	Pharmaceutical cluster	Titanium cluster	Chemical cluster
2008	11.32	16.67	-0.14
2009	-2.56	18.74	-0.79
2010	9.84	0.52	-0.27
2011	-9.87	11.73	-0.06
2012	0.42	23.8	0.41
2013	-2.41	27.27	0.56
2014	2.43	33.18	0.58
2015	7.34	36.63	4.68

In table 2, it is shown that all the clusters are observed with growth dynamics of cost efficiency in comparison with the average industry value, this fact corresponds to the cluster theory, which justifies getting the additional effects for enterprises operating within the cluster and receiving a larger amount of profit compared to independent industry participants respectively.

The following point of the research is the analysis of the of cluster group significance in the industry.

TABLE III. THE LOCALIZATION COEFFICIENT OF THE CLUSTERS OF SVERDLOVSK REGION⁶

Year	Pharmaceutical cluster	Titanium cluster	Chemical cluster
2008	1.05	2.53	1.98
2009	0.93	2.88	1.54
2010	0.95	2.49	1.89
2011	0.70	3.45	1.30
2012	0.47	4.04	1.08
2013	0.41	3.82	0.77
2014	0.43	4.24	1.03
2015	0.39	2.66	1.07

As table 3 shows, the coefficient of localization with a value of more than 2 is observed only in the titanium cluster. That is why one can speak about a full formation of the titanium cluster on the territory of Sverdlovsk region. The chemical cluster over the last eight years shows the coefficient of localization of more than 1, and the pharmaceutical cluster is poorly formed because the coefficient of localization is less than one.

⁵ Calculations conducted according to the data provided by the data-processing system SPARK-Interfax <http://www.spark-interfax.ru/>, and the unified interdepartmental statistical information system (EMISS) <https://www.fedstat.ru/indicators/start.do>

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Analyzing the dynamics of the indicators, one can observe the moment when the effects of the cluster work become visible. For the titanium cluster, this is 2011; for the chemical - it is 2015; and for the pharmaceutical - it is 2014. One can also conclude that the formation of the titanium cluster is the

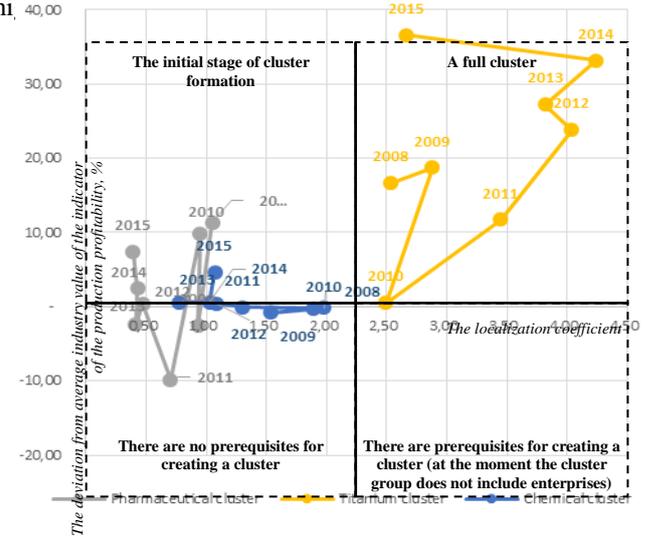


Fig. 4 Grouping of clusters of Sverdlovsk region by the stages of the ontogenesis⁷

Thus, the conducted analysis allows speaking about the realization of the so-called monoclusteral implosion scenario, which provides for the gradual development of the cluster in the core sector of the economy, when, as the result of the protoclusters formation identification, the regional management system gradually "grows" a full cluster and brings it to the inter-regional economic space [9].

IV. DISCUSSION

The obtained results allow considering the cluster as a special form of interaction between the enterprises of the region, which makes it possible to get by its member additional effects and to have a significant impact on the economy of the territory and it is the result of the evolution of forms of interaction. That is, the cluster acts as a sign, a description of a certain state of interaction between economic subjects.

The results of the research also suggest the possibility that the cluster is an intermediate link in the evolution of integrative structures, which go beyond the borders of a particular area including an increasing number of economic subjects during the formation of significant effects. Today the highest form of such structures is large multinational corporations, whose activities extend to the all open markets of the world. In recent years, in the works of many authors, the output of the cluster beyond a particular area can be traced to.

For example, in the works of E. Limer were considered clusters with a high level of correlation export in the analysis of the trade at the national level.

⁷ Compiled by the author

In the works of M. Porter, it is written: "In a global economy with a rapid transportation, high speed transfer of information and availability of markets could be expected to reduce the importance of location. However, the reverse is true. Sustainable competitive advantages in the global economy are often highly localized and occur due to the concentration of highly specialized qualification and knowledge, institutions, competition, business and demanding consumers" [28].

V. CONCLUSION

The author proposes a method of identification of regional industrial cluster formations and the results of the study stage of ontogenesis clusters of Sverdlovsk region. The main parameters in the identification of clusters as a represented procedure defined deviation from the average value of the profitability index for a cluster of enterprises and the coefficient of the cluster localization. The results showed that the three cluster groups formed the greatest prospects for the formation of the cluster; they can provide full titanium cluster performance, which is far superior to the pharmaceutical and chemical clusters.

The practical part of the study is a conclusion about the relevance of state support for the titanium cluster formed in Sverdlovsk region, which has prospects for further sustainable development.

The study also concluded that the cluster is an intermediate level in the evolution of integrative structures that effect the formation beyond the specific area, including a growing number of economic entities. The highest form of such structures are currently the major transnational corporations, whose activities extend to all open markets of the world.

In conclusion, it is possible to admit that the traditional cluster model of regional economic development defines a cluster as a single-industry formation, which is localized within a certain area, while modern researches reveal a new trend of cluster development, which goes beyond the traditional model. A decrease in the value of geographical concentration with a simultaneous internationalization of economic activities of the cluster is observed.

This paper proposes a methodology of statistical study of the processes of clustering economy and an algorithm for estimating industry-specific prerequisites for formation of regional clusters. The study showed that many of the economic clusters in Russia have a real basis for their establishment in the form of industrial specialization of the region. Further development of regional clusters based on industry specialization should lead to the sustainable development of the region and the country.

The main tasks of the cluster policy at the territorial level become: the development of the general concept of the formation and development of cluster structures; distribution of powers in the field of cluster policy; support cluster initiatives on development of advanced industries of the territories; development of the infrastructure of clusters; formation of the structure and objectives of the cluster members and others.

The obvious process is the evolution of the inter-firm linkages from industrial clusters based on the territorial location of production to the development of regional industrial clusters, and through the development of an international component to the formation of the international industrial clusters. Each of the evolutionary phases implies an increase in the complexity of the interaction among economic subjects.

Therefore, one can state that the specificity of international clusters is that the cluster entities are residents of different countries; they are connected in technological chains and complement each other; cooperate and compete simultaneously.

This fact allows one to define a new direction for further researches in the sphere of development interaction strategies of industrial clusters on the international level with a perspective of the output on the formation of international clusters as sustainable systems for engagement of a wide range of interrelated, interdependent and mutually reinforcing stakeholders. These stakeholders are localized at the territories of two and more countries, operating in related industries and with a similar level of skills and technology development. Besides, they are involved in the joint creation of goods and/or services, providing overall synergistic effect in the development of the relevant territories and the diffusion of innovations among them.

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