STANDARDIZED ANALYSIS OF THE CROSS-REGIONAL CLUSTERS’ EFFICIENCY (THE CASE OF RUSSIA)

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The processes of disintegration in the 90th of the last century negatively influenced the Russian Federation economic environment. Differentiation of economic activity conditions sustained essential growth. According to experts the total volume of cross-regional economic relations became 4 times lower. Practically the split of economy into export sector and sector working for home market took place. Meanwhile, the achievement of sustainable economic growth, the rise of the country’ competitiveness and transfer to the innovative model of development depends directly on successful overcoming of autarkic tendencies. It requires the reform of cross-regional relations’ system aimed at efficient use of territories competitive advantages both in the interests of definite regions and state in whole. Solution of the defined problems is in the competence of federal and regional authorities interested in transition of the Russian industry into the innovative setup.

Keywords: cross-regional interaction, cluster, innovative development, economic mathematical methods

Introduction

Innovative development today belongs to the most topical problems, both for science and for public authorities in any country. In its turn, this type of development is impossible without territorial integration which is to provide free movement of production, investment and labour resources between regions of a country.
In Russia, formation of the full-fledged cross-regional integration is complicated by significant distances between the territories and insufficient development of transport communications inside the country. This leads to serious cross-regional differences in terms of production, scientific and natural potentials. Besides, a significant share of the already formed production and trade relations inside the country and also with the former republics of the USSR have been distorted during the 1990s as a result of transition to market economy.

Consequently, Russian economy is characterized by rather distinct interregional heterogeneity and disbalances in its spacial development, both socioeconomic and innovative. This conclusion is additional proved by vast empirical data, available from both Russian and foreign studies.

Most of the researchers in this field are unanimous in the statement that cross-regional differentiation in Russia does not only exist – it actually leads to a range of rather negative externalities. Agreeing with most of the ideas of the “new economic geography” here, we think that inequality in the territories’ development levels within market economy would be impossible to smooth fully. At the same time, artificial smoothing of per capita incomes between the regions as performed by federal authorities through resources redistribution may lead to lower rates of economic development of the country as a whole.

Therefore, externalities from cross-regional differentiation should be more positive. And this would be possible it provided cross-regional cooperation effects dominate over the effects from cross-regional competition. This would enable widening the spacial borders of economic activity of one regions by means of the others. In this case cross-regional differentiation will become not only the resource increasing the welfare level in particular regions, but would be also the catalyst of innovative development of the national economy overall.

Theoretical and practical importance of reforming the cross-regional relations’ system which is an integral element of the innovative development of the regions and the country, have defined our choice of the objective and the subject matter for this research.

**Background**

The means of the cross-regional economic interaction were formed during a long period of time simultaneously with social division of labour and with the development of production and trade relations. Therefore, considerable attention of scientists, from A. Smith with his theory of absolute and relative advantages to the present time, is paid to the problems of studying nature, forms, advantages and effects of cross-territorial interaction and cooperation of economic subjects. Survey of the modern academic literature on this subject revealed that problems of cross-regional interaction are considered by analysts either in the context of globalization when economic subjects co-operate with each other with the aim to meet international competition (Torre et al., 2005, Ovcharenko, 2001, Etzioni, 1965) or in the light of inequality of special regional development (Pyke et al., 1992, Song, 2007, Plikhun et al., 2009). These problems are examined in the frames of “center-periphery” theory, the theory of growth poles and development centers, the theory of territorial industrial engineering.

A great number of published works concerning the problem of study are devoted to the levels’ correlation of cross-regional interaction and to the innovative activity (Audretsch,

Despite the obvious research results in the field of cross-regional interaction and its influence on economic development, scientific achievements connected with evaluation of such interaction effects have been sufficiently incomplete.

It is necessary to mention that in scientific works the description of cross-regional interaction effects is presented, as a rule, on the base of interdisciplinary analysis: modern institutional economic theory, theory of communication, theory of complex systems, synergetics and even logistics. Thus, for example, Russian sociologist A.E Shastitko (2009) considers cross-regional interaction, namely clusters, in the logics of modern institutional economic theory. The author notes that special interdependence which allows deriving particular rent appears between participants of cluster when technical independence is combined with factual one. L. Leidsdorf (2008) describes the effects of three agents of development interaction (representatives of science, business and government) from the position of the theory of communication. In his opinion interaction of three agents lowers the level of uncertainty in the process of decision-making and allows creating new knowledge right along. A.A. Bogdanov (2003) examines the effects of interaction from the position of system analysis. In combining some components into organized system, it is happened the addition of their “activities” (i.e. positive demonstration) giving considerable effect as far as “the opposition” (i.e. negative impacts opposing “activities”) is not formed.

After the analysis of the Russian and foreign scientists’ experience the authors concluded that the considered approaches to the evaluation of cross-regional clusters efficiency it is not adequately taken into account the influence of clusters on the showing of territories’ development. Moreover, the existing methods do not allow applying these indicators as universal ones with regard to the economic systems different in the levels of development.

Theoretical and methodological grounds for this study have been shaped by numerous works in the field of geopolitics, production forces allocation, network economy, industrial regions’ development and clusters. The information and empirical basis for this research consists of Russian legislation and regulatory acts; information & analytical databases available online on the site of the Federal Service for Public Statistics of Russian Federation; results of the sociological surveys; other materials published in Russian and foreign research sources; media sources.

Several key approaches are suggested for application in this study.

First of all, the methodology within institutional evolutionary economic theory. It would enable defining the regularities in formation and development of the institutes needed for the functioning of cluster structures as the leading form of cooperation between economic subjects.

The second approach is based on the ideology of hierarchical analysis of territorial economic systems. Within the framework of the hierarchical approach we study the processes taking place at various levels of the economy. This approach also includes the
STANDARDIZED ANALYSIS OF THE CROSS-REGIONAL

analysis of the hierarchical structure of the participants and their interconnection within particular regions. It also covers the determination of opportunities for their cross-regional efficient cooperation.

Thirdly, we aim at application of mathematical statistics methods (including correlation and regression analysis, grouping/clustering method and cluster analysis).

Applying these three methodological approaches to the analysis of the effectiveness of cross-regional clusters would increase the soundness of our conclusions and would also provide a chance to pay attention to those aspects which remain uncovered/understudied in case if only one of these approaches is applied.

Main Focus of the Study

On the base of generalization and classification of methods used for analyzing clusters’ efficiency in the process of their operation we proposed standardized analysis of the cross-regional clusters’ efficiency.

Under the efficiency of cross-regional cluster’s operation we suggest understanding of qualitative and quantitative change of regions’ activity indicators, the indicators of branch operation as well as of target groups in cross-regional cluster (entrepreneurial structures, power bodies, social organizations and population).

Proposed procedure of identification and analysis of efficiency of cross-regional clusters’ operation includes 7 stages (Figure 3) which could be symbolically divided into three groups:

1) group (Stages 1 и 2) – Algorithm of clusters’ identification;
2) group (Stages 3-5) – Algorithm of clusters’ analysis;
3) group (Stages 6-7) – Algorithm of clusters’ efficiency evaluation.

Stage 1. Grouping of territories according to the level of clusterization potential

In previous works (Yolokhova et al., 2016) the authors created the algorithm of cluster potential calculation for revealing the types of regions which was based on Etzkowitz-Leydesdorff (2000) “triple helix” concept. This concept was used for calculating region’s cluster potential on the base of three indices: “Index of quality of life and infrastructure development” (X), “Index of industrial development” (Y), “Index of education level and technological development” (Z). The suggested system is correlated with the elements of “triple helix” in the following way: “Index of quality of life and infrastructure development” – “Power”, “Index of industrial development” – “Business”, “Index of education level and technological development” – “Science”. It can be judged by these indices if the region is ready for clusterization, i.e. how efficient is the budget funding of cluster structures’ development in this territory.

Every index is calculated on the base of definite statistics. Selection of indicators’ group for every index and further calculation of integral indices is carried out in 5 steps.

Step 1. It is selected groups of indicators completely characterizing each of three indices and their multicollinearity control is carried out.

Appraisal of calculation algorithm was made by the authors for the regions of Russia on base of 2013 statistics. So, there were selected 4 indicators characterizing index X, 1 indicator – index Y and 5 indicators for index Z (Table 1). All of them were recommended for the calculation of integral indices.
Table 1 - System of indices characterizing cluster potential
(made by co-authors)

<table>
<thead>
<tr>
<th>Integral Indexes</th>
<th>Statistical indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Index of Quality of life and infrastructure (X)</td>
<td>Total area of living space per head on the average</td>
</tr>
<tr>
<td></td>
<td>Population size per one hospital bed</td>
</tr>
<tr>
<td></td>
<td>Density of public hard-surface roads</td>
</tr>
<tr>
<td></td>
<td>Pollutant emissions from stationary sources</td>
</tr>
<tr>
<td>2. Index of Productive potential (Y)</td>
<td>Volume of factory shipments (work, services) according to the type of economic activity “Processing production”</td>
</tr>
<tr>
<td>3. Index of Scientific and technical and educational potential (Z)</td>
<td>Headcount of staff involved in research and development</td>
</tr>
<tr>
<td></td>
<td>Number of students trained by the programs of undergraduate studies</td>
</tr>
<tr>
<td></td>
<td>Internal research and development costs</td>
</tr>
<tr>
<td></td>
<td>Number of university teachers at educational institutions of higher education</td>
</tr>
<tr>
<td></td>
<td>Volume of innovative goods, work, services in the rate of total volume of fulfilled work</td>
</tr>
</tbody>
</table>

*Source: author’s version.*

Step 2. Evaluation of asymmetry characterizing the degree of distribution asymmetry with respect to the county’s average value of indicator is carried out for every indicator. At that, if the resulting distribution is asymmetric (the value of asymmetry indicator is more than 0.5), in order to evening-out the influence of “spikes” (extreme values) on the value of calculated index the value of indicator is transformed according to formula:

\[
\bar{x}_{ij} = k \sqrt{x_{ij}}
\]

where \( \bar{x}_{ij} \) – transformed value of i-indicator in j-region;
\( x_{ij} \) – datum value of i-indicator in j-region;
\( k \) – degree of asymmetry (takes on values from 2 to 4 against the asymmetry ratio)

Step 3. For uniformity and comparability all indicators are normalized by linear transformation:

\[
\bar{x}_{ij} = \frac{\bar{x}_{ij} - \bar{x}_{i \_min}}{\bar{x}_{i \_max} - \bar{x}_{i \_min}}
\]

where \( \bar{x}_{ij} \) – normalized value of i-indicator in j-region;
\( \bar{x}_{i \_min} \) – minimum value of i-indicator in Russia;
\( \bar{x}_{i \_max} \) – maximum value of i-indicator in Russia.
Step 4. For every region it is calculated indices, characterizing cluster potential of the region as arithmetic mean of normalized values of corresponding groups of indicators. Cluster potential (CP) of the region is calculated according to the formula:

$$CP = \frac{X + Y + Z}{3}$$

Thus, it will be defined 3 indices for every region resulting from calculation according to the algorithm mentioned above. These indices characterize the level of power, science and business development, and on the base of their values it has been calculated the value of the region’s cluster potential.

Further derived indices could be applied in two directions. Firstly, they may be used for grouping territories according to the level clusterization potential. Well-known algorithms of mathematical clusterization (hierarchical clusterization, algorithms of squared error, selection of connected components, Kokhonen maps, etc.) are used for grouping. Secondly, they may be used for comparison of territories according to the level of life quality and infrastructure development, industrial potential, technological and educational potential and definition of vectors of their further growth. Every territory against the degree of X, Y, Z maturity is arranged in matrix point (see Fig. 1). For example, territory under the number N has high level of quality life but low level of production, technological and educational potentials, so territory N is arranged in HLL point.

<table>
<thead>
<tr>
<th>Productive potential (Y)</th>
<th>Quality of life and infrastructure (X)</th>
<th>Scientific and technical and educational potential (Z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

Figure 1 - Matrix of maturity degree of the territory’s clusterization potential
(Source: author’s version)

In the process of results’ interpretation it is defined the set of vectors of further development and interaction of territories. Thus, for the territory N natural line of development is the increase of production, technological and educational potentials. Such increase is possible to be achieved in the process of integration with the territory in HMM point. It should be mentioned that when the territories are chosen for cooperation it is evaluated the intensity of the existing cross-regional flows of goods and services, funds, cash assets, etc.
After the first stage it is defined the territories to the best advantage acceptable for creating cross-regional clusters.

Stage 2. Definition of specialization of cross-regional cluster enterprises-participants

Step 1. Definition of priority-driven branches of development and types of activity in the studied territories.

Priority-driven branches of development are defined on the base of territories’ legal documents. They may include both long-term strategies and medium-term forecasts of development.

Step 2. Analysis of specialization degree of corresponding branches and types of their activity for every territory.

To define the degree of specialization of any branch or type of activity it is necessary to calculate the rate of specialization \( LQ \). Branches interrelated in cluster jointly use the common labour market where special skills are formed. The rate of specialization \( LQ \) is determined as the ratio of employment: the share of employed in the territory’s industry \( (E_{ij}) \) in total volume of employment in the studied territory \( (E_i) \) in comparison with the share of employed in the branch of national industry \( (E_j) \) of total volume of national employment \( (E) \):

\[
LQ_{ij} = \frac{E_{ij}}{E_i} / \frac{E_j}{E}
\]

The value \( LQ > 1 \) for the branch shows higher level of the region’s specialization in this branch than the national average, and it is interpreted as the indicator of existing competitive advantages in the examined branch. If in this situation the average annual job growth rate is positive, the examined branch shows the dynamic progress and attracts new cadres (IPA, 1997).

Thus, according to the calculation results matrix of coefficients for branches’ specialization in territories is filled (Table 2).

<table>
<thead>
<tr>
<th>Branch</th>
<th>Territory 1</th>
<th>Territory 2</th>
<th>...</th>
<th>Territory N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Branch 1</td>
<td>( LQ_{11} )</td>
<td>( LQ_{12} )</td>
<td>...</td>
<td>( LQ_{1N} )</td>
</tr>
<tr>
<td>Branch 2</td>
<td>( LQ_{21} )</td>
<td>( LQ_{22} )</td>
<td>...</td>
<td>( LQ_{2N} )</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Branch K</td>
<td>( LQ_{M1} )</td>
<td>( LQ_{M2} )</td>
<td>...</td>
<td>( LQ_{MN} )</td>
</tr>
</tbody>
</table>

Table 2 - Matrix of coefficients for branches’ specialization in territories
(Source: author’s version)

Step 3. Definition of branch of specialization for cross-regional cluster creation

Table 3 presents total information about existing branches of specialization in priority-driven spheres of economy of the analyzed territories. The table if filled in the following way: if \( LQ_{ij} > 1 \), in the appropriate cell of table we put “+”, in the opposite situation it is put “-”.

Further on the base of expert appraisal it is defined the branch of specialization for creating cross-regional cluster. There could be several branches of specialization. In this case there appears the opportunity to create cross-regional cluster including several branches of specialization or several clusters.
STANDARDIZED ANALYSIS OF THE CROSS-REGIONAL

Table 3 - Priority-driven spheres of economy according to the types of activity of the analyzed territories
(Source: author’s version)

<table>
<thead>
<tr>
<th>Branch</th>
<th>Territory 1</th>
<th>Territory 2</th>
<th>…</th>
<th>Territory N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Branch 1</td>
<td>+</td>
<td>+</td>
<td>…</td>
<td>-</td>
</tr>
<tr>
<td>Branch 2</td>
<td>+</td>
<td>+</td>
<td>…</td>
<td>+</td>
</tr>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>Branch K</td>
<td>-</td>
<td>-</td>
<td>…</td>
<td>+</td>
</tr>
</tbody>
</table>

Stage 3. Definition of target groups in cross-regional cluster.

Definition of target groups in cluster will be made according to the procedure developed by M. Porter (2000). Firstly, it is defined the core of cluster from which technological chains of interrelated with it enterprises are driven in the vertical direction; in horizontal direction industries which use common with the core factors of production, technology and deliveries are identified. Secondly, there selected special groups within the cluster providing specialized practices, technology, information, capital and infrastructure, everything, which forms the base of competitive advantages. Thirdly, it is identified governmental and other legal structures influencing the behaviour of cluster’s participants. They form rules, principles, incentives which influence the character and intensity of local competition.

Stage 4. Definition of key parameters and integral indicator of cluster’s efficient functioning on the base of expert appraisal.

Experts of scientific community, business managers and official authority are the important resource of information about prospects and problems of regional industrial development.

At the first step in the process of experts’ polling it is formed the set of parameters characterizing the efficiency of cross-regional cluster functioning. At the second step parameters are grouped into blocks and experts are proposed to range the received collection of parameters in every block. At the third step in every block the most significant indicators are selected. At the fourth step it is used numerical score: experts assign weight to all indicators in every block and estimate the degree of their influence on success of cluster’s functioning. At the fifth step it is calculated the integral index for every block of indicators by summation of weighted estimates. At the sixth step it is defined the integral indicator of cross-regional cluster functioning as the root of corresponding degree from the product of integral indices of every block of indicators.

Considering the subjectivity of expert appraisal and in order to analyze results there applied such methods of mathematical statistics as formation of generalized estimator, analysis of hierarchies and method of determination of experts’ consensus degree.

Stage 5. Identification of key parameters and integral indicator of efficient cluster functioning on the base of statistics and legal documents.

Step 1. Determining of combination of indicators for the evaluation of cross-regional cluster efficiency. The problem of combination of indicators for evaluating clusters’ effectiveness continuous to be debatable. Andersson singles out such indicators as: the number of firms in cluster, employment, production rate (efficiency), export, the number of innovative projects, profits and modification of these indicators in time. Naumov V.A. (2006), Kostyukevich D.V. (2009) propose to use the following characteristics as criteria:
production structure of cluster, resource potential, investment activity, economic indexes. T.V. Zadorova (2009) applies only four indicators for evaluation of the clusters’ efficiency: cluster’s share in industrial production of the region, cluster’s share in total number of employed people, index of labour productivity at the enterprises of cluster, cluster’s share in the export structure of the region.

To evaluate the efficiency of cross-regional cluster the authors propose the system of factors and indicators developed on the base of factor analysis application (Soshnikova et al., 1999). (Table 4). Before the beginning of factor analysis all indicators are standardized.

Table 4 - Factors and indicators of cross-regional cluster's efficiency evaluation
(Source: author’s version)

<table>
<thead>
<tr>
<th>Name of factor</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor of cross-regional cluster significance (S)</td>
<td>1. Indicators “coefficient of localization”, “size”, “focus” calculated according to the employment statistics</td>
</tr>
<tr>
<td></td>
<td>2. Indicators “coefficient of localization”, “size”, “focus” calculated according to statistics of factory shipments (executed work, rendered services)</td>
</tr>
<tr>
<td></td>
<td>3. Indicator of uniqueness</td>
</tr>
<tr>
<td>Factor of interdependence of cross-regional cluster’s participants (I)</td>
<td>1. Number of ties among cluster’s participants</td>
</tr>
<tr>
<td></td>
<td>2. Indicator cross-regional cluster’s localization potential</td>
</tr>
<tr>
<td>Factor of economic effectiveness of cross-regional cluster (EE)</td>
<td>1. Average monthly wage of personnel within cross-regional cluster</td>
</tr>
<tr>
<td></td>
<td>2. Profits</td>
</tr>
<tr>
<td></td>
<td>3. Investment in fixed assets</td>
</tr>
</tbody>
</table>

Step 2. Calculation of integral indicator of cross-regional cluster effectiveness.

Integral indicator of cross-regional cluster effectiveness (CCE – Cross-regional cluster effectiveness) is equal to cube root from the product of estimation factors’ value (Table 5). Factors’ values are calculated in the process of factor analysis:

\[
CCE = \sqrt[3]{S * I * EE}
\]

Stage 6. Analytical estimation of effectiveness of cross-regional cluster’s functioning

Integral indicators obtained at the 5th stage show the effectiveness of cross-regional functioning. The level of integral indicator is estimated by experts. Also its value is compared with calculated value of the previous period, effectiveness growth is estimated. The indicator of effectiveness could be also compared with the industry’s average one.

Estimation of the influence of cross-regional cluster’s operation on the indicators of territories’ development (GRP, GRP growth, index of industrial production, investment in basic capital, etc.) could be made by the methods of mathematical statistics, namely correlation-regressive analysis and variance analysis.

Stage 7. Monitoring of corrective actions realization and receive of feedback from cluster participants

Thus, among the advantages of the proposed procedure it could be marked out the following ones:
- the procedure may be used both for the estimation of operation effectiveness of the cluster located in the territory of one region and in the territory of several regions;
- the set of indicators used for calculating integral indicator takes into account special features of regions’ activity, of separate industry and directly of cluster’s participants.

**Solutions and Recommendations**

As it has been shown by our research in cross-regional clusters there arise unformalized situations which are difficult to define by mathematics. Application of analytical methods is insufficient for their description. Besides, processes taking place in clusters are long-continued ones. So, we consider the methods of system dynamics to be of essential application in cluster modeling. They makes possible to create simulation model of cross-regional cluster aimed at predicting effects of managerial decisions directed to the region’s development. Analysis of output data of cross-regional cluster simulation modeling allows, first of all, making qualitative conclusion which describes the dynamics of its development and secondly, quantitative conclusion which makes possible to predict the change of economic, social and financial indicators of regional development.

General directions of cross-regional relations’ development could be the following:
- development of innovative infrastructure;
- conducting market studies aimed at defining potential and prospects of cross-regional export;
- creation of the system of goods marketing in the regions of Russian Federation by intensification of exhibition and fair activity and organization of trade representation network;
- creation of dataware system for the subjects of cross-regional market.

**Conclusion**

In the issue of cross-regional cooperation and interaction competitive advantages of some subjects will create incentives for economic activity growth in the territories of other subjects. This process will promote transition of Russia to the innovative way of development.

The conducted research shows that high cross-regional differentiation inevitably leads to the enlarged number of decelerating territories and intensification of cross-regional contradictions. This fact makes considerably difficult to pursue common policy of social-economic transformations by power bodies in the most number of developing countries including Russia. In Russia one of the general directions of reformation in the field of innovative development is the support of clusters. However, regulatory control carried out by authorities does not provide the requirements of developing mutual advantageous ties among regions of Russia.

In this work is was, firstly, justified the significance of cross-regional interaction for innovative economic development; secondly, there were defined the problems being the obstacle for the development of the mentioned interaction; thirdly, it has been formulated the concept of the country’s competitiveness growth at the expense of cross-regional clusters; fourthly, it has been developed the procedure of analysis of cross-regional clusters’ effectiveness. In the issue of cross-regional cooperation and interaction competitive
advantages of one subject will create incentives for economic activity growth in the territory of the other subjects. This process will promote transition of Russia to the innovative way of development.

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