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Stages and Tools of Evaluation of Cluster Operation (Case Study of Shipbuilding Cluster of St. Petersburg)

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The article discusses the clusters that provide innovation and competitiveness of the economy. Methods and evaluation stages of the operation of the cluster are analyzed. The method for evaluation of the cluster is presented.

Keywords: Cluster, economic growth, innovation potential, identification, evaluation, shipbuilding.

Many theoretical approaches to territorial innovative development[1-4] underline, that innovations and economic growth (spatial or regional theories and models of economic growth)[5-6] are mainly geographically concentrated. Business has a trend to be accumulated and concentrated in certain locations. Malmberg, Solvell, & Zander, 1996 defined four different types of clusters: Cities, Industrial districts, Creative regions, Clusters.

The concepts of theories of new forms of spatial organization of production[7-13] highlight the following approaches to interpretation of regional clustering (Table 1).

E. S. Kutsenko[14, 15] confirmed that formation and development of clusters makes it possible to provide both promotion of innovations and increase in economic well-being in the region (Fig 1).

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METHOD

Related Subjects

The phenomenon of cluster as an object of economic agglomeration of interrelated enterprises in a certain area is known from the times of handicrafts. However, the theoretical base of cluster concept was founded early in the 19-th century by *Von Thunen* and his followers *Launchardt* and *Weber* in their works devoted to economics and agglomeration (Von Thunen, 1826; Launchardt, 1882; Weber, 1909). Nevertheless, many researchers (Bathelt, 1998; Ketels, 2003; Krugman, 1991; Scott & Storper, 1992; Audretsch, 1998) believe that it was A. Marshall in his Principles of Economics (A. Marshall, 1890) who was the first to prove that the efficiency of companies and results of their business directly depend on their locations and geographical proximity of economic agents (Fig. 2, 3).

Despite numerous works by other researchers of cluster theory, *Michael E. Porter*, an American economist, Professor of Harvard Business School is considered to be the founder of modern cluster concepts with his works devoted to industrial clusters (The Competitive Advantage of Nations, 1990) and then to regional clusters (On Competition, 1998).

To summarize the analysis of foreign and Russian references it could be mentioned that at present there are significant gaps in application of the cluster concept both at theoretical and at methodological levels. Uncertainty in definition and complicated character of revealing of cluster boundaries in space should be considered as the major drawback of the applied term "cluster". As a consequence, numerous interpretations of the term "cluster" exist (see Clara, 2000; Regional clusters…, 2002; Martin, Sunley, 2003). However, it is possible to detect that main inherent elements of a cluster are geographical proximity, inter-company network, and inter-organizational or institutional network; being combined together, these properties differ cluster from any other social—economic phenomenon.

Despite rapidly increasing amount of published works on clustering there is still a lack of works devoted to evaluation of their operation. Most of the existing studies on this subject are confined to statement of official statistics (in case of conventional indices of company business) or data obtained by alternative ways (if evaluation of certain undisclosed parameters or quality characteristics is required), on the basis of which the conclusions are derived in dominating position of clusters in certain industry or in certain territory. However, no attention is actually paid to the factors stipulating these leading position and growth potential. Thus, one of major tasks of investigation into cluster is development of procedure facilitating measurement of direction and degree of interactions between factor and resulting attributes in local clusters.

Analysis of the works devoted to this issue makes it possible to state that evaluation of clusters is not a single action but solution of complex problem, which could be subdivided into five main stages—lines of a certain sequence. This peculiar hierarchy is based upon identification, which is actually a primary evaluation of cluster.

There are numerous tools including both quantitative and qualitative methods suitable for practical solution of problems of identification and evaluation of cluster operation – from simple measurement of specialization (for instance, by means of location quotient) and to procedures based on analysis of matrices of inter-industry balance. For instance, E. Bergman and E. Feser highlight two major groups of cluster study: micro-oriented (micro-level) methods and methods of inter-industry cluster analysis (Bergman, Feser, 1999).

Micro-level methods include such labor-consuming studies as local surveys, application of Delphi-methods, focus-groups, etc. Nevertheless, Bergman and Feser mention that micro-level approaches turn to be low efficient within detection of industrial clustering at regional level, since due to their labor consuming nature do not facilitate formation of holistic approach to development of regional economics. The following analytical approaches are considered as an alternative to micro-level procedures, which are classified as inter-industrial methods of cluster identification (Table 2): - analysis of experts' opinion; - investigation into location quotients; - analysis of matrices of inter-industry balance (product exchange); - analysis of matrices of inter-industry balance (innovation exchange); - network analysis (see Bergman E.M., Feser E.J. Industrial and regional clusters… 1999).

Despite the fact that the first two approaches are classified by these authors as inter-industrial, they are rather of miAro-industrial type. Only three remaining approaches, based on analysis of matrices of inter-industry balance and being numerical (quantitative), differ significantly from the methods of micro-level analysis. Herewith, the analysis tools used in these approaches are based on the following methods: method of principal components and factor analysis; - multivariate statistical cluster analysis; - theory of graphs.

As could be noticed, solution of the problem of cluster identification is restricted not only by the analysis tools but by database and required measuring elements.

The method based on statistics analysis has its disadvantages which are related first of all to existence and adequacy of statistic data.

The methods based on analysis of indirect data and expert evaluations make it possible to perform more thorough and accurate determination of clusters (and protoclusters) in a region. In addition, there occur problems with objectivity of applied data, verification of the obtained results, and scaling-up of investigations. In this regard it seems reasonable to combine methods based on analysis of these two sources of information.

According to definition, cluster possesses completeness of three key features (Fig 4).

The stages of efficeincy evalution of cluster operation are illustrated in Figure 5. They are as follows:

1. Identification of cluster
2. Evaluation of cluster, evaluation of geographical concentration, evaluation of Aommunication between members of the cluster
3. Calcuation of integral index.

In whole it is proposed to evaluate the efficiency of cluster operation by calculation of the following indices:

a) Calculation of location quotients, size, focus.
b) Calculation of internal communication (cooperation) between the members of cluster.
c) Calculation of innovative potential.
d) Calculation of integral index.

In order to determine total integral index, characterizing cluster development, the method of principal components is applied:

$$Cl_j = \sum_i principal\ component$$

where *principal component* $_{ij}$ is the value of principal component of clustering for the *i-th* group of the *j-th* region and *Clj* is the integral clustering index of the *j-th* region.

RESULTS

Now let us evaluate cluster operation according to the proposed procedure for the case of shipbuilding cluster of St. Petersburg. Shipbuilding is a historic designation of St. Petersburg. Human resources in the field of shipbuilding of St. Petersburg exceed 42 thousand workers (this is 16 % of total personnel occupied at processing enterprises of the City). Output of produced goods by shipbuilding enterprises of the City amount to 30 % of overall production in the field of shipbuilding in the country and more than 50 % of overall production of military industrial sector in St. Petersburg.

Calculation of internal communication (cooperation) between the members of the cluster. Since the cluster is a network structure, then the maximum amount of communications can be determined by all possible pairwise communications:

$R = n (n – 1) / 2$, where n is the amount of members of the cluster. The shipbuilding cluster of St. Petersburg consists of 43 members.

$$R = n (n – 1) / 2 = 43*(43-1) / 2 = 903$$

Using the V. A. Graicunas theory and recommendation of Ober-Krie Dzh. it is possible to prove the efficiency of cluster approach. The Graicunas equation is as follows:

$$N=n[(2n-1 +(n-1)],$$

where N is the amount of interactions (contacts), n is the amount of participants in interrelations.

Interaction

a) Overall set of inter-cluster interactions can be conveniently presented in the form of

Table 1. Approaches to regional clustering

'Schools of thought'	Important factors forming the basis of growth and operating clusters
Industrial districts	External economic systems + mutual confidence and 'industrial environment' leading to increasing innovations
'Californian School'	Vertical decomposition, decreasing operational expenses, and specialized local labor market + agreements, unofficial rules and habits
'Scandinavian School'	Innovations as study of localized process due to importance of 'sticky' non-encrypted knowledge
Porter industrial clusters	External economic systems enhanced by proximity (better access in order to introduce factors, local competitiveness and local customers)

symmetrical n-dimensional matrix of intensities of inter-cluster interactions. *cluster capacity*

b) In order to study and to evaluate efficiency of cluster operation it would be reasonable to apply economical mathematical simulation and to develop a model adequately describing the processes of

Table 2. Methods of evaluating the effectiveness of the cluster

Methods	Submethods	Advantages and disadvantages
Quantitative	Systems of indicators (Balanced systems of indices)	+ Facilitates revealing of disproportion and development of these or those regions - Analysis is restricted with one year - Subjective selection of indicators
	Regression models (Dependent variable - amount of patents, expenses in R&D, amount of innovative products)	+ Possibility to outline extent and direction of influence of certain factors - Very large database + Accuracy of evaluations
	Integral indices based on the system of indicators	+ Possibility to rank test objects - Peculiar for systems of indicators - Subjectivity of determination of indicator weights included in index
Qualitative	In-depth non-formalized interview	+ Facilitates determination of qualitative characteristics of test object, which cannot be evaluated quantitatively (effect of social network, influence of non-codified knowledge) - Impossible to provide generalizing evaluations
Combined	Questionnaire survey System of indicators based on questionnaire results (point-based system) Combination of system of indicators (regression model) and in-depth interview	+ Combines advantages of quantitative and qualitative methods + Facilitates partial elimination of disadvantages of quantitative and qualitative submethods

Table 3. Key indicators of the importance of cluster groups[17]

Equations	Description
$LQ = \frac{Emp_{ig}}{Emp_g} / \frac{Emp_i}{Emp}$	LQ – location quotient; E_{mpig} - employees in the *i-th* industry in the *g-th* region; E_{mpg} - total employees in the *g-th* region; E_{mpi} - employees in the *i-th* industry; *Emp* - total employees
Size $= \frac{Emp_{ig}}{Emp_i}$	Size (S) – Size of cluster group *i*; E_{mpig} - employees in the *i-th* cluster group in the *g-th* region; E_{mpi} - employees in the *i-th* cluster group
Focus $= \frac{Emp_{ig}}{Emp_g}$	Focus (F) – Focus of the *i-th* cluster group; E_{mpig} -employees in the *i-th* cluster group in the *g-th* region; E_{mpi} - employees in the *g-th*

cluster interactions.

c) Regional cluster can be considered as complex organizational system, the state of which can be evaluated by a set of factors or criteria. Let the evaluated organizational system be described on the basis of preset partial criteria vector $K = (k1, ..., ki, ..., kn)$

d) ARA model (ARA: actors; resources; activities) for efficiency evaluation of interaction of partners in market networks

e) Geographical proximity quotient, intersectoral flow quotient.

Table 4. Calculation of indicators

Employees in the *i-th* cluster group in the *g-th* region	44250
Total employees in the *g-th* region	2848000
Total employees in the *i-th* industry	75000
Total employees	71258000

Table 5. Indicators of significance shipbuilding cluster of St. Petersburg

Location quotient (LQ)	Size quotient (S)	Focus quotient (F)
15	0.59	0.01553722

Table 6. The system of indicators for assessing the innovative potential of the industrial cluster[19]

Groups of indicators	Subgroups	Index
Input indicators	Financial support	Expenses for innovations (% of total turnover)
		Expenses for R&D (% of total turnover)
		Expenses for R&D per one company included into economic agglomeration
		Portion of expenses for R&D in added value
		Specific weight of expenses for technological innovations in total expenses of company
	Scientific potential	Portion of companies performing R&D activities
		Portion of issued patents in submitted patent applications
	Resource potential	Index of renovation (modernization) of fixed assets in fiscal year (amount of purchased new equipment in fiscal year)
		Average annual cost of fixed industrial assets
		Returns on assets (sales per ruble of fixed industrial assets)
		Provision with raw stuff and materials
	Human potential	Portion of employed by enterprises of cluster in total personnel
		Portion of employees with higher education, %
		Portion of involved into R&D activity
		Portion of employees involved into innovative activity
	Infrastructure	Business-incubators, technological parks, venture funds
		Amount of educational entities involved in training of post-graduates (doctoral students)
Output indices	Cluster results	Specific weight of companies performing innovative activity
		Specific weight of innovative goods, works, services in overall scope of shipped goods, works, services
		Portion of export in innovative products in export structure, %
		Efficiency of personnel involved in researches and development, production of cluster in terms of average annual number of employed
		Growth rate of new enterprises, %
		Portion of gross value added in gross regional product

Table 7 . Models of the calculation of the innovation potential

Model of calculation	Equation of integral index of groups	Equation of innovation potential
using mean arithmetic weighted value	$G_j = \frac{\sum_{i=1}^{n} g_i * a_i}{\sum_{i=1}^{n} a_i}$	$G = \frac{\sum_{j=1}^{m} G_j * \beta_j}{\sum_{j=1}^{m} \beta_j}$
using mean geometric weighted value	$G_j = (\prod_{i=1}^{n} g_i^{a_i})^{1/\sum_{i=1}^{n} a_i}$	$G = (\prod_{j=1}^{m} g_j^{\beta_j})^{1/\sum_{j=1}^{m} \beta_j}$
using mean harmonic weighted value	$G_j = \sum_{i=1}^{n} a_i / \sum_{i=1}^{n} \frac{a_i}{g_i}$	$G = \sum_{i=1}^{n} \beta_j / \sum_{j=1}^{m} \frac{\beta_j}{G_j}$

Table 8. The value of the integral index

Item	Model of evaluation of innovation potential of shipbuilding cluster of St. Petersburg	Integral index of innovation potential of shipbuilding cluster of St. Petersburg
1	using mean arithmetic weighted value	0.72
2	using mean geometric weighted value	0.69
3	using mean harmonic weighted value	0.65

Calculation of Innovative potential

An important feature of cluster is its innovation orientation: clusters as a rule are formed where a breakthrough in the field of engineering and technology occurs or expected to occur with subsequent output to new market niches. In order to measure the readiness degree of cluster to pursue a strategy oriented at implementation of new products it is proposed to apply the notion "innovative potential"[18].

Most of analytical and scientific works devoted to clusters are based on application of various quantitative indices (Raines, 2003). The system includes both quantitative and qualitative indices.

Some possible indices of cluster evaluation are summarized in Table 6. They are neither final nor complete, but on their basis it is possible to evaluate the cluster potential. Most researchers within evaluation are concentrated on economic indices of cluster, clusters are multi-sided, this should be taken into account while evaluating numerous indices. Of course, even more complicated methods of evaluation of cluster

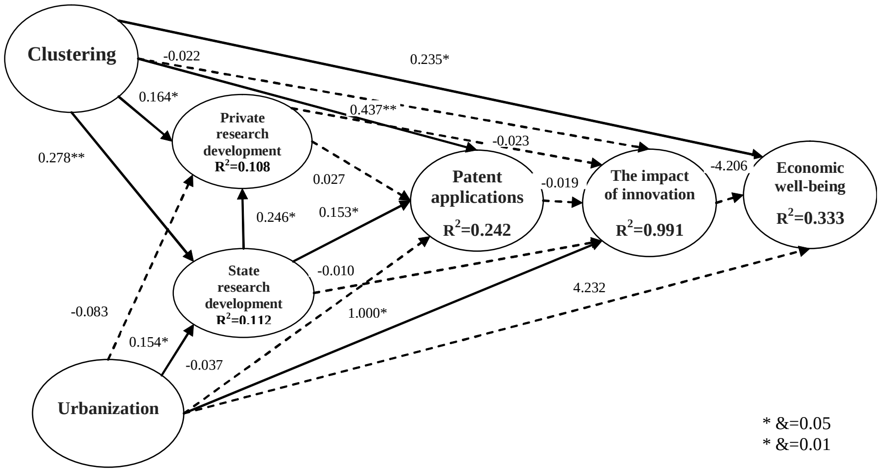

Fig. 1. The results of the evaluation of the modified model, Lindquist for the subjects of the Russian Federation

development exist, such as business profiling (analysis of company in terms of product), analysis of supply chain, etc.

The evaluation and monitoring of clusters is complicated by indices as a function of time, since it is known that clusters provide results with time.

Evaluation of innovation potential of shipbuilding cluster of St. Petersburg (Table 7-8, Figure 6)[20].

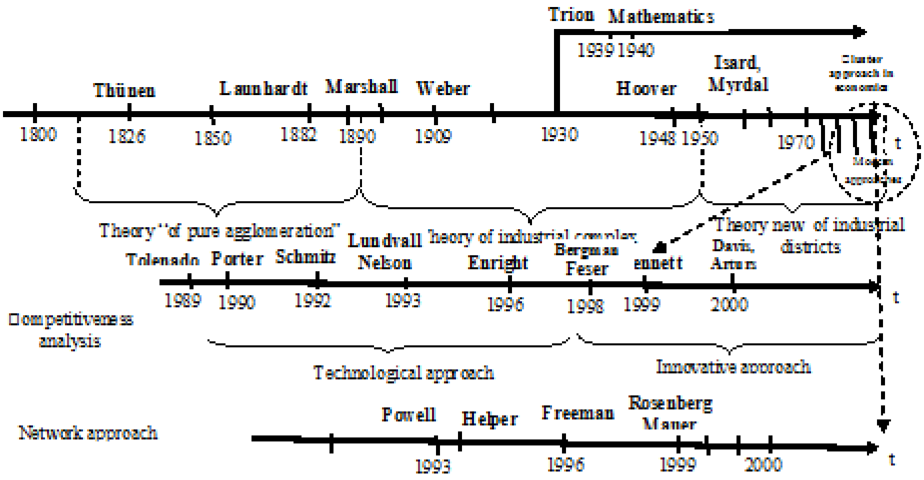

Fig. 2. Formation and development of the cluster approach in Western economic thought

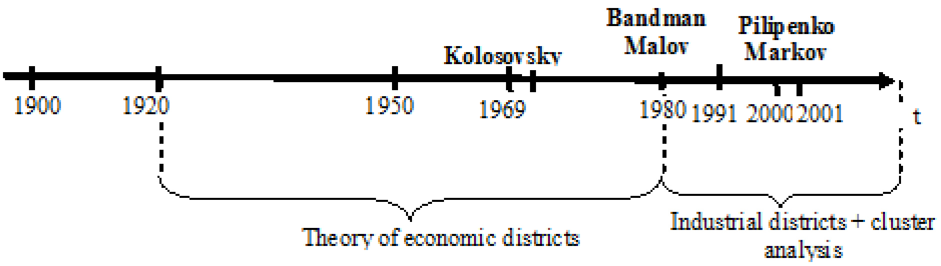

Fig. 3. The development of the cluster approach in the domestic economic thought

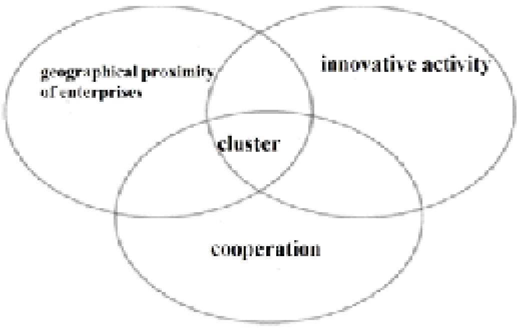

Fig. 4. Options for the combination of three key features of the cluster

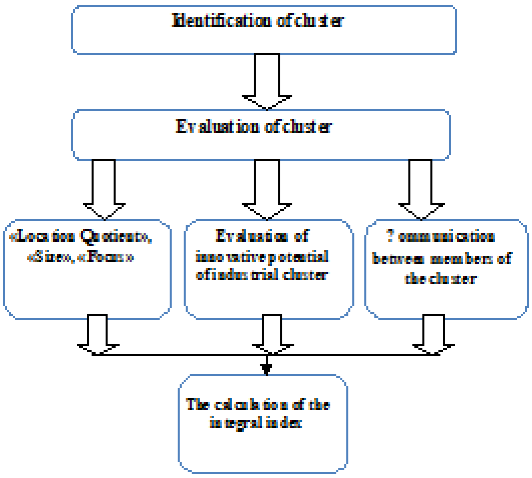

Fig. 5. Stages of evaluating the performance of the cluster

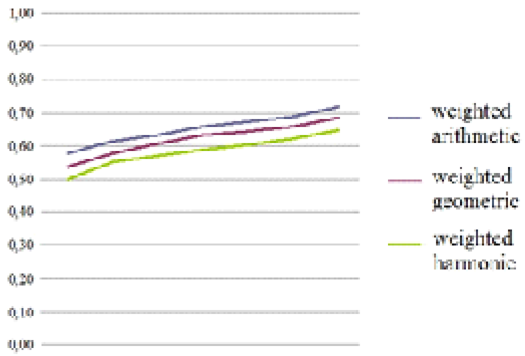

Fig. 6. The value of the integral index of the innovative capacity of the clusters depending on the method of calculation

DISCUSSION

Analysis of the obtained results has demonstrated that in general the evaluation indices of innovation potentials in various approaches are different. However, in the scope of the applied calcaulation model they are similar. Therefore, the applied procedure for evaluation of innovatopn potential is valid.

The difference between the obtained results by various models can be attributed to mathematical peculiarities of each model.

CONCLUSIONS

The performed analysis of the shipbuilding cluster has revelead that not all possiblities are applied in order to improve competititvenes. In order to improve the existing situation it is necessary to perform a set of measures aimed at increase in level of labor management, production, management, increase in level of business and personal qualities of employees, increase in managerial and engineering indices.The article is prepared with the support of the Ministry of Science and Education of the Russian Federation (project No. 26.1303.2014/K)

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