

# *Aspects of the functioning of industrial clusters as network economic systems*

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**Abstract** — Today clusters are a popular concept in economic circles. However, these integrated structures are still poorly studied from a scientific point of view. Unresolved problems include the issues of technology functioning, improving the efficiency of these integrated structures in industry, the use of modern management technologies in these structures. The special need for research is due to the need to obtain a more complete picture of the internal processes in innovative associations and modern management technologies in industry. The effects arising in networked integrated economic structures need to be studied, since they are the result of a causal relationship between the participants in such structures. The object of attention of the authors are industrial clusters. The subject of research is the relations arising in the process of functioning of industrial clusters. The research was based on materials about clusters in the regions of the Russian Federation and the world. Objective: to identify the features of communication of participants in industrial clusters. The study focuses on the analysis of the structural effect arising in the process of communication of participants in industrial clusters. The result of the work is to obtain new knowledge about the technology of functioning of industrial clusters, which is of theoretical and practical importance for the management of these economic systems.

**Keywords**— *industrial cluster; structural effect; functioning technology; economic systems; interaction mechanism.*

## I. INTRODUCTION

The industrial cluster is a group of geographically adjacent and integrally interacting companies and related organizations that operate in a particular industry and mutually complement each other [1, P.56]. An industrial cluster should also be understood as a group of geographically localized enterprises, research-and-production and financial companies, linked together in a technological chain or oriented towards a common market of resources or consumers [2, P.58]. The industrial cluster is a modern form of economic systems, they complicate the competitive environment due to the emergence of a significant number of cooperative and integration links.

Let's pay attention to the effect of communications between the participants of the modern diversified industrial cluster. Formally, industrial clusters are associations of

industrial enterprises of various sizes and forms of ownership, the purpose of which is to increase the competitiveness of each participant and the industry as a whole due to the synergy effect into a single structure. Structure is the internal structure, location, order of individual elements of the market, their share in the total volume of the object. Signs of any structure are: close connection between its elements; certain stability of these bonds; integrity, a set of data elements.

Industrial clusters from other types of clusters are distinguished features of the products (industrial use) and size. As a rule, they are very large in terms of the territorial location of the association at the sectoral level, a feature of the products of which is the high capital intensity (an indicator that shows the value of fixed assets per unit of output issued by an enterprise) and a complex technological process. The specific characteristics of industrial clusters can also include a large number of participants of different profiles within the same industry who implement a sequence of operational and functional actions, while the cluster members do not compete with each other, but work together to achieve a common goal - production of the final product demanded by the market and bringing the maximum possible income to producers. The technological process of producing cluster products creates a large number of internal communications. The organizational structure of the cluster is based on relationships. At the same time, the nature of the interaction of its participants is networked, since it is horizontal integration in this case that contributes to the formation of a strictly oriented chain of dissemination of new knowledge, technologies and innovations.

The most important difference of the cluster from other forms of economic associations is that the cluster companies do not go to a complete merger, but create an interaction mechanism that allows them to maintain the status of a legal entity and at the same time cooperate with other economic entities that form the cluster and its limits. Relationships within the cluster generate completely new opportunities for the development of production and its innovative renewal.

Networks, unlike hierarchies, are based on horizontal links and operate on the basis of principles different from the

market and hierarchy. Their characteristic feature is trust, self-organization and cooperation [3, P.18]. Some scientists do not distinguish between the concepts of network structures and clusters, and, speaking of clusters, refer to network structures as a whole [4].

Features of the functioning of industrial clusters today are one of the most interesting questions for economists studying integrated structures. Clusters, in the opinion of the authors of this article, are able to fully reveal the essence of network collaboration in the real sector of the economy and demonstrate the prospects for the development of industries where cluster models of the functioning of associations are used.

## II. LITERATURE REVIEW

At the turn of the 1980-1990s. Clusters were perceived as an advanced type of production agglomerations (hence the notion of "industrial clusters"), allowing participants and their home territories to achieve particular competitive gains. Later, the factor of territorial localization of clusters was added to this (hence the term "regional cluster" emerged), as well as their description as network and non-hierarchical entities [5].

The concept of "cluster" in the economy was first introduced by M. Porter in 1990 and applied to the sectors of the economy and organizations. Porter believed that clusters are geographically concentrated groups of interrelated companies, specialized suppliers, service providers, firms in relevant industries, as well as organizations related to their activities (for example, universities, standardization, trade associations) in certain areas, competing, but at the same time leading joint work [6, P. 197]. He also gave such a definition of clusters - it is a form of network that occurs in a certain territory, where the proximity of companies and institutions provides certain forms of community and increases the regularity and influence of interactions [7, P.102]. Before Porter, the term "cluster" was used by Soviet and Russian economists - A. Gor'kin, L. Smirnyagin, Swedish business economists - K. Fredriksson, L. Lindmark to refer to clusters of enterprises in space, as well as to describe processes production concentrations.

Questions of an innovative approach to the management of industrial structures were considered in the works of Russian scientists A.V. Babkina, Yu.V. Vertakova, V.S. Kudryashova, N.I. Lygina, I.E. Risina, E.V. Sibiriyakov, N.V. Sirotkina. Foreign authors-researchers of the functioning of clusters in industry are: A. Marshal, M. Delgado, D. Zeng, E. Nogales, M. Porter, P. Stern. The main issues touched upon within the framework of research are issues related to the mechanisms of operation of integrated structures in the economy, the influence of integration processes on the sectoral structure of the economy and the efficiency of functioning of integrating structures. The study of the works of these authors showed that the problem of relations between cluster members is not at the meso level, within the structure, little attention is paid. The technology of functioning of industrial clusters from inside is poorly studied, it determines the relevance of identifying features of the functioning of industrial clusters at the present stage of economic development.

Modern scientists believe that the creation of a high-quality system for modeling, forecasting and managing the socio-economic development of industrial clusters is an urgent task [8, p. 79], and clusters can be the basis for the formation of a national and regional innovation system. The authors of this study consider it appropriate to consider the task of identifying the features of the functioning of industrial clusters as economic systems of the meso-level in terms of trends in economic development at the current stage.

## III. RESEARCH METHODOLOGY

To understand the relations of the participants within the industrial cluster, we apply the abstraction method. We will conventionally call each of them a cluster molecule, and the aggregate knowledge base of each cluster member will be represented as a set of atoms that form this molecule. Thus, cluster atoms are parts of information, knowledge possessed by cluster molecules, and which are used in the technological process of production of the final product, as well as in communications within the cluster. It is atoms that are conditional units of information and knowledge for interchange. Moreover, the size of these units in this case will not matter, because the exchange takes place at a qualitative, meaningful level. When atoms enter into other molecules, there is an increment of knowledge in the receiving molecule. Accordingly, these interactions lead to an increase in the information potential of cluster molecules involved in the exchange. As a result, the total molecular knowledge base increases, and the industrial cluster begins to grow qualitatively in the internal information field, i.e. the network begins to train itself. This may continue for different periods of time in each cluster, until full interpenetration occurs, when the molecules acquire the maximum possible volume of atoms. Then, to develop a cluster, it will be necessary for new members (molecules) to enter it, or to replace them to restore the exchange of new particles, or to upgrade the skills of existing ones to obtain new atoms (particles of knowledge). Only if one of these conditions is fulfilled will industrial clusters develop. If the molecule is not involved in the exchange, then it has no prospects for long-term work in an industrial cluster, since it becomes obsolete and cannot correspond to the general molecular level.

Let us call this phenomenon a structural effect, obligatory for the functioning of an industrial cluster. Concretize the concept. The structural effect is the result of the process of sharing knowledge of participants in industrial clusters, due to the network features of the interaction. In the process of work, the cluster participants (molecules) enter into relations of knowledge and technology exchange, which leads to an increase in knowledge about improving the production of goods and services in the industry of each of them.

To prove this hypothesis, let us represent in the form of a scheme the level of knowledge of a participant in an industrial cluster (molecule) at the initial stage of communications in a cluster and after a certain period of interaction. Suppose that the cluster molecule X before entering the cluster had a level of knowledge  $x$ . In the process of work, it can increase it at the expense of information components (atoms) of other participants (molecules), because molecules exchange knowledge in the process of production

technology. This is inevitable, since industrial clusters are a technological chain of suppliers and manufacturers for the production of products that cannot be created by individual molecules. Therefore, the process of convergence of molecules in this case can be stated as one of the working conditions for any cluster formation in industry. To the level of knowledge  $x$ , the X molecule adds atoms of other molecules and begins to look like  $x$  with particles from a, f, p, k, b .... At the same time, molecule X gives a part of its information atoms to other cluster members. At the same time, the greater the number of PPH members entering into relationships in the internal network, the larger the X molecule becomes, since at the same time it retains its level of knowledge and takes on particles from other molecules (Figure 1). Those particles that molecule X transmits to other molecules do not reduce its level of knowledge, since it does not lose them during transmission. Similarly with other molecules during interchange. Mathematically, this can be demonstrated by calculating the increment of the argument.

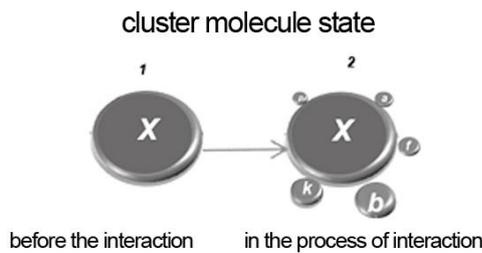


Fig. 1. The result of the interaction of industrial cluster molecules. Compiled by the authors.

Consider two argument values: initial  $x$  and new  $x$ . We call the difference  $x$  and  $x_0$  the increment of  $x$  and express it as  $\Delta x$ . The greater the value of  $h_0$ , the greater the  $\Delta x$ . We call the value of  $\Delta x$  the resulting structural effect.

If  $x = x_0$ , then the effect is zero. Those. The level of knowledge of the molecule does not change in the process of interaction with other molecules. If  $x$  is more  $x_0$ , then the effect will be negative for X, because X has much more knowledge than all other participants, but positive for other participants. In this case, the level of knowledge of the molecule X taken by us exceeds the level of knowledge of other molecules, and X does not receive anything as a result of the interaction. If  $x$  is less than  $h_0$ , the effect will be positive. A positive exchange is possible if the level of knowledge X is less than the level of knowledge of other participants in the industrial cluster, i.e. Knowledge of X molecule is acquired.

The values of the structural effect depending on the result are presented in Table 1.

TABLE 1. THE VALUES OF THE STRUCTURAL EFFECT

Condition	Result	Result Value
$x = x_0$	$\Delta x = 0$	zero effect
$x > x_0$	$\Delta x < 0$	negative effect
$x < x_0$	$\Delta x > 0$	positive effect

To determine the effect of the increment, we use the increment function. The existence of the derivative of the

function  $y = f(x)$  and the value of the derivative depend on the choice of the point  $x_0$ . Therefore, the derivative of the function is itself a function of the point  $x_0$ . The points  $x_0$  and  $x_1$  form on the X axis, respectively, the points  $y_0$  and  $y_1$ . If we take  $y_0$  from  $y_1$ , then we will get the function increment.

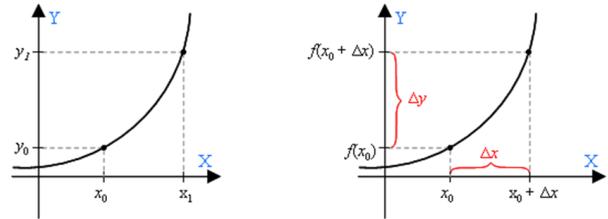


Fig. 2. The increment of the function  $f(x)$

So, in the function  $y = f(x)$  with respect to certain points  $x_0$  and  $x_1$ :

the difference  $x_1 - x_0$  is called the increment of the argument, and the difference  $y_1 - y_0$  is called the increment of the function. But  $y_0$  and  $y_1$  are dependent variables (dependent on  $x$  values). We write them like this:  $f(x_0)$  and  $f(x_1)$ . Therefore, the increment of the function is the difference  $f(x_1) - f(x_0)$ . The increment is denoted as  $\Delta$  (delta) (1):

$$\Delta x = x_1 - x_0 \tag{1}$$

then (2)

$$\Delta y \text{ (or } \Delta f) = f(x_1) - f(x_0) \tag{2}$$

If the increment  $\Delta x$  is added to  $x_0$ , then we obtain the point  $x_1$ .

$$x_1 = x_0 + \Delta x \tag{3}$$

(see figure 2). Then the point  $f(x_1)$ , marked on the first figure as  $y_1$ , can also be designated differently (4):

$$f(x_0 + \Delta x) \tag{4}$$

We derive the function increment formula (5):

$$\Delta y = f(x_0 + \Delta x) - f(x_0) \tag{5}$$

and set the parameters for this function. Let us use the abstraction methodology and introduce the following parameters for our cluster model: the number of participants in the integrated structure is initially 10. We denote the number of cluster participants by the parameter  $n$ . Then, the increment function limit wake be of the following form (6):

$$y = n^2 \tag{6}$$

This equality can be explained by the fact that if all 10 cluster members share a knowledge unit with all cluster members, then the amount of knowledge will be elevated to the second degree (similar to the like). Thus, we get the maximum value of the argument  $x_1$ , in this case it is 100 units of knowledge.

However, in practice it is almost impossible to obtain the technologically maximum exchange of communications

for various reasons: from organizational to individual psychological, therefore, fragmentary exchange between a part of cluster members takes place most often. If one ( $n = 1$ ) participant in the linear interaction mode will share with a certain number of cluster participants, then we will receive data according to Table 2. In this case,  $n = x_0$ .

TABLE 2. MATRIX OF KNOWLEDGE SHARING. OPTIONS WITH  $N = 1$

<b>x0</b>	1	1	1	1	1	1	1	1	1	1
<b>x1</b>	2	3	4	5	6	7	8	9	10	11
<b>Δx</b>	1	2	3	4	5	6	7	8	9	10

The increment function of the argument is as follows (7):

$$f(x) = x_0 + \Delta x \tag{7}$$

Calculate the increment of the argument and the increment of the function (8), (9):

$$\Delta x = (x_1) - x_0 \tag{8}$$

$$\Delta y = f(x_0 + \Delta x) - f(x_0) \tag{9}$$

Find the values of the increment of the function  $\Delta y$  at values  $x_0$  and possible  $\Delta x$  according to the formula of the function. In this case, the parameters  $f(x_0 + \Delta x)$  will always vary from 1 to 10 (according to the number of possible combinations of knowledge transfer to the participants of the association). Subsequently, it can be set by a parameter from 1 using the variable  $n$  with the values  $n + 1, 2, 3, \dots$ . Thus, we get the matrix of values of the increment function for each type (table 3).

TABLE 3. THE MATRIX FOR OBTAINING DATA FOR DETERMINING THE FUNCTION OF INCREMENT WITH  $F(x_0) = 1, N = 10$

<b>f(x0)</b>	1	1	1	1	1	1	1	1	1	1
<b>(x0 + Δx)</b>	2	3	4	5	6	7	8	9	10	11
<b>f(x0 + Δx)</b>	1	2	3	4	5	6	7	8	9	10
<b>Δy</b>	3	8	15	24	35	48	63	80	99	120

As a result of calculations, the matrix of  $\Delta y$  values at  $x_0 + \Delta x = \{1 \dots 10\}$  will have the following form (Table 4):

TABLE 4. THE MATRIX OF  $\Delta Y$  VALUES FOR THE CLUSTER, WHERE  $N = 10$

<b>f(x0) / (x0 + Δx)</b>	1	2	3	4	5	6	7	8	9	10
<b>1</b>	3	8	15	24	35	48	63	80	99	120
<b>2</b>	4	12	21	32	45	62	79	96	119	140
<b>3</b>	5	16	29	40	55	72	91	112	135	160
<b>4</b>	9	20	33	52	69	86	105	128	153	180
<b>5</b>	11	24	39	56	75	96	119	144	171	200

<b>6</b>	13	28	45	64	85	108	133	160	189	220
<b>7</b>	15	32	51	72	95	120	147	176	207	240
<b>8</b>	17	36	57	80	105	132	161	192	225	260
<b>9</b>	19	36	63	88	115	144	175	208	243	280

The obtained data allow us to conclude that the involvement of one participant in the communication process gives a significant increment to the structural effect. Figure 3 shows a diagram of the increase in the general level of knowledge when the number of participants involved in the communication process changes. It is clearly seen that any action associated with an increase in participants leads to a general increase in the total volume of knowledge inside the cluster.

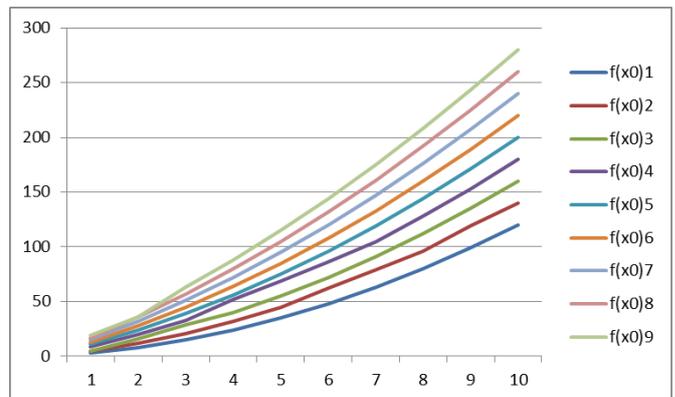


Fig. 3. Diagram of the increase in the structural effect  $\Delta y$ .

#### IV. THE RESULTS OF EXPERIMENTAL STUDIES

In the course of the study, we found that networks, unlike hierarchies, are based on horizontal links and operate on the basis of principles different from the market and hierarchy. Their characteristic feature is trust, self-organization and cooperation [9, p.81]. Some scientists also do not distinguish between the concepts of network structures and clusters, and, speaking of clusters, referring to network structures as a whole [10, P. 35]. At the enterprises organized by the network principle, new factors of success act, not similar to the traditional ones. For these enterprises, it is important not so much to own, as to have free and effective access to new resources - ideas and information. For them it is important, first of all, the participation of staff in the development of solutions and flexible control. What is essential is not the concentration and centralization of production directly, but the organization of effective network interaction between all participants in the production process [11, p. 96]. Many scientists believe that the creation of a high-quality system for modeling, forecasting and managing the socio-economic development of industrial clusters is an urgent task [12, p. 188], and clusters can become the basis for the formation of a national and regional innovation system [13, p. 66].

The structural effect that we found in industrial clusters can be viewed as a completely new phenomenon in the functioning of integrated industrial structures, which is directly related to the efficiency of unions. The found values

of the structural effect are measurable. We empirically came up with a formula for the structural effect arising in the process of communication between cluster members. We calculated the increment of each action with the addition of a new participant in the exchange of information and knowledge in the network industry structures.

## V. THE DISCUSSION OF THE RESULTS.

The results obtained can be applied in practice in the work of the Centers for Cluster Development of Regions, since they give an idea of the functioning of industrial clusters as economic systems that is not described in the scientific literature earlier. The data obtained as a result of the conducted research can be useful for creating clusters, as well as for building up the internal interaction of their participants at the present stage of development of integration associations.

The results of the study allowed to make the assumption that the meso-level systems are of interest from a scientific point of view.

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