ECONOMIC INDICATORS OF DEVELOPMENT CLUSTER PARTNERSHIP SYSTEMS OF THE NATIONAL ECONOMY

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Abstract. In this article, the author has developed ideas about the monitoring system for scientific, technical and industrial development of cluster partnership systems. Using the methods of graph theory, an adjacency matrix and a graph are constructed, expressing the degree of econometric and logical interconnection of indicators of innovative development of cluster partnership systems. The structure of key indicators of innovative development of cluster partnership systems has been developed; new indicators for the Ukrainian accounting system have been proposed and substantiated.
Keywords: *clusters structures, intercluster partnership, indicators of innovative development, graph theory, matrix of undirected graph.*

Introduction

The statement of the audit task is due to the lack of a harmonized system of indicators of economic (including innovative) development at the global, European and national levels, which is objectively reflected in the analytical models of the relevant monitoring missions ("Global European Cluster Observatory"; OECD; World Bank, etc.). We found 2 reasons for the lack of a solidarity about development indicators: 1) inconsistency of national plans and statistical forms for both industry and cluster structures; 2) the incompleteness of the scientific discussion about the key indicators of the economic development of cluster structures. It is clear that the first reason is predetermined by the second: in the absence of an agreed base of indicators at the global level, it is inappropriate to change the national principles of statistical observation.

Literature review. Scientific search for key indicators of innovative development of cluster partnership systems is based on the search for relationships, correlation relationships of variables. The most interesting results are presented in scientific works: Prim A. L., Amal M., Carvalho, L. (2016); Chen Y. M., Lin Y. H. (2014); Giovannetti E. (2006); Heblich S., Kipar S. (2010); Rayman-Bacchus L., Wu Y. (2011); Bergman E. M. (2000); Britton J. N. H. (2006) and others. The objective limitation (to generalization) of the scientific results of foreign scientists is the national localization of the correlation analysis sample, various internal drivers of cluster development. Based on this classification, the differentiation of financing of academic entrepreneurship is proposed to be considered as an adequate measure of harmonization of state policy on small innovative enterprises, taking into account the features important for the results of innovation.

Nevertheless, several generalizing conclusions based on the coincidence of the detected interrelation of indicators are quite objective. The author singles out 4 conclusions that formulated the framework and boundaries, the criteria for scientific research:

- for the objectivity of monitoring, 10 variables (maximum) are sufficient, forming the core of the observation, all other indicators are factors of their decomposition;
- the core of monitoring includes interrelated internal (innovative) and external (market) factors of cluster partnership systems;
- there is an objective direct relationship between volume market indicators (share, sales volume) and indices of innovation activity;

- logically obvious, interconnected factors are not always found in direct correlation (mathematical) relations, which determines the inclusion of indicators not only in an econometrically proven, but also logically obvious connection.

These theses are defined by the author as a theoretical basis for research and synthesis of a set of variables for goal setting and monitoring of economic innovative development of cluster partnership systems. Of course, in the national economy this task is also relevant both for monitoring the economic innovation development of cluster structures and for the purpose of international comparison of their competitiveness. However, the lack of legislation on cluster development at the national level and the lack of a system of monitoring indicators determine the relevance of this study.

Research methodology. Consider the results of study of economic indicators of the development of cluster partnership systems.

The indicators used in national practice can be classified according to the economic functions of cluster structures (suggested by the author): entrepreneurial; financial and investment; scientific and technical (innovative); production. Within the groups, we have identified 35 independent indicators (*Table 1*), excluding the decomposition variables.

Table 1.

The structure of indicators of the development of cluster partnership systems by groups («gr.»)

Code/gr.	Indicator	Unit measurements
Entrepreneurial		
E01	Number of participants in the Cluster Partnership System (CPS)	**units**
E02	The number of people employed in all subjects of the CPS	people
E03	The share of employed in small enterprises - subjects of the CPS	%
N01	Number of jointly implemented projects	units
Financial and Investment		
F01	Aggregate revenue of CPS subjects	UAH million
F02	Investment volume of CPS subjects	UAH million
F03	Investments from off-budget sources	UAH million
Scientific and Technical (innovative)		
I01	Product innovation	%
I02	The volume of R&D carried out by the subjects of the CPS	UAH million
I03	R&D volume carried out jointly with foreign organizations	UAH million
I04	Number of patents per inventor in specialized R&D organizations	patents per person
I05	Number of Technology Startups	units
I06	Average Added Value added in CPS	%
I07	The cost of OIP created by the subjects of the CPS	UAH million
N02	The volume of intellectual property assets acquired by entities within the CPS (transfer)	UAH million
Production		
P01	Number of high-performing jobs	units
P02	Performance	UAH million per person (CPS employee)
P03	The cost of raw materials, materials and products in the turnover of CPS subjects	UAH million

Note: Compiled by the author according to regulatory documents and domestic profile publications. The indicator code is used in subsequent synthesized graphs.

Analysis of the structure of variables (*Table 1*) allows us to conclude that it reflects in a balanced way the economic aspects of cluster partnership systems identified by the author (groups), allows

for volume and index comparisons, and build time series. Reflection of internal economic interaction, cooperation is built on 2 variables: the number of jointly implemented projects (N01, units); the volume of intellectual property assets acquired by entities within the cluster partnership system (N02, UAH million). The variable (N01) has low transparency from the point of view of the type of cooperation in the "project", it can reflect both logistic, service and other types of partnerships, it is not obvious that it belongs to the innovative activity of the CPS. The variable (N02) reflects the processes of transfer of intellectual property assets between developers and production (other internal customers), that is, financial contracts for the acquisition of R&D results. Formally, this variable reflects the required indicator (the index when referred to the I02 variable) of the "scientific and technical" cooperation of the CPS. But the index of "production" cooperation is not presented in the monitoring structure.

The second significant drawback of the presented set of indicators, the author determines the lack of reflection of the relationship between the economic development of cluster partnership systems and the external environment, the environment - industries and markets. All variables are endogenous to the economic activity of CPS, not measurable from the point of view of the development of the industry (for example, market share, "density," consolidation, etc.). That is, the criterion (da Rocha A. et al., 2009) of reflecting the position of cluster partnership systems in the industry is not met, entrepreneurship indexes (including innovative) are poorly represented.

Of course, these shortcomings of the complex of variables are quite understandable from the position of the "initial" level of cluster development of Ukraine, the formation of the process of innovative interaction in the cluster partnership system. But setting the task of managing innovative cooperation objectively requires expanding the composition of indicators both in terms of observing the level of "production" cooperation and in terms of interaction with sectoral development.

In this context, the author investigated economic indicators of the development of CPS, both used in foreign practice and formulated in the publications of reputable researchers. It should be noted that the foreign scientific discussion is quite active and is aimed at continuous refinement of indicators, primarily due to the objectivity of the evolution of the institutional structure of cluster structures (Feser, Bergman, 2000). Indicators that do not duplicate the national monitoring complex of CPS, while maintaining functional classification, are compiled in *Table 2*.

Note that most of the 40 variables identified by the author belong to the group of "entrepreneurial," expresses the position of cluster partnership systems in sectoral development. The most characteristic variable is the (P05, %) share of the cluster in the national market (in the industry), expresses the influence of the CPS on industrial development, the economy of the industrial sector. And the index (P04, %) - the share of value added produced by CPS entities in total turnover is the desired variable expressing the level of "production" cooperation of CPS.

Table 2.

Economic indicators of cluster structure development used in foreign practice

Code/gr.	Indicator	Author
	Entrepreneurial	
E04	Share of exports in gross sales	Prim A.L., Amal M., Carvalho, L. (2016, [17]); da Rocha A., Kury B., Monteiro J. (2009, [3])
E05	Share of the cluster structure in the national market (in industries)	Lai Y.L., Hsu M.S., Lin F.J., Chen Y.M., Lin Y.H. (2014, [11])
E06	"Density" - the share of national industry enterprises included in the cluster structure	Bertolini P., Giovannetti E. (2006, [1])
E07	Employment structure in cluster structure differentiated by production, R&D and marketing	Falck O., Heblich S., Kipar S. (2010, [4])
E08	"Cluster Structure Self-Organization Level" - number of registered new legal entities included in the cluster structure	He Z., Rayman-Bacchus L., Wu Y. (2011, [9])
Code/gr.	Indicator	Author

E09	"Network Level" - the number of Cluster Entity entities that have contracts with more than 1 cluster member	Feser E.J., Bergman E. M. (2000, [5])
E10	Level of cooperation of entities with differentiation by elements of cost-cost structure	Britton J.N.H. (2003, [2])
Financial and investment		
F04	Revenue Growth Rate	Wolfe D.A., Gertler M.S. (2004, [18])
Scientific and Technical (Innovative)		
I08	Average value of the OIC unit at adjustment to balance sheet, market valuation or for sale	Jun S., Park S.S. (2013, [10])
I09	Availability (number) of open platforms innovation in the cluster structure	Niu K. H., Miles G., Bach S., Chinen K. (2012, [14])
I10	Share of employees in the scientific and technical sphere to the total number of employees trained by educational organizations cluster structure	Zhao W., Watanabe C., Griffy-Brown C. (2009,[19])
I11	Cluster Structure "Knowledge Capacity" - Ratio of Cluster Total R&D Costs to Full Turnover	Niu K. (2010, [15])
Production		
P04	Share of added value produced by cluster entities in total turn	Giuliani E., Pietrobelli C., Rabellotti R. (2005,[8])
P05	Share of industrial workers in the total number of employees trained educational organizations of the cluster structure	Zhao W., Watanabe C., Griffy-Brown C. (2009,[19])

Note: Compiled by the author

Discussion of research result. But the formal addition of the national monitoring complex (*Table 1*) with these indicators will not solve the task economic indicators of development cluster partnership systems of the national economy, it is necessary to determine the indicators precisely as an interconnected complex.

In this context, the author conducted a study of econometric and logical relationships of variables. The first (econometric) are disclosed through the decomposition of the equations quite obvious in the disclosure of the variables in *Tables 1 and 2*. The second (logical) – on the basis of the economic laws of economic activity "resources – results" formulated in the scientific literature (the previously designated principle of Feser E.J., Bergman E.M. (2000).

Research result. The collection of identified relationships form relations of variables, which can be represented as an incompatibility matrix (graph theory tool), *Table 3*. Within the matrix, the author separates econometric ("1") and logical ("2") relationships that allow you to see the field of relations.

In this article, based on the Inconsistency Matrix, the author constructed an undirected graph of the relationship of indicators, presented in *Fig. 1*. The author chose a radial projection of the graph, which allows you to see, first of all, the hierarchy and, in the second, the relationship of nodes. The inscription next to the node (vertex) (*Fig.1*) indicates its weight (valency 1) in the graph, obtained by calculating the relative number of bonds (edges) of their consolidated ones. From the position of analysis (within the framework of graph theory methods), the nodes (expressing indicators) with the highest weight are defined as key, structure-forming. Accordingly, the obtained graph (*Figure 1*) allows solving the problem of highlighting the set of key indicators of innovative development of cluster partnership systems. The author identified 9 indicators with a cut-off of weight on the lower horizon of 0.8, the aggregate weight and characteristics of which are shown in *Table 4*. It is they that form the core of the system of long-term planning of innovative development.

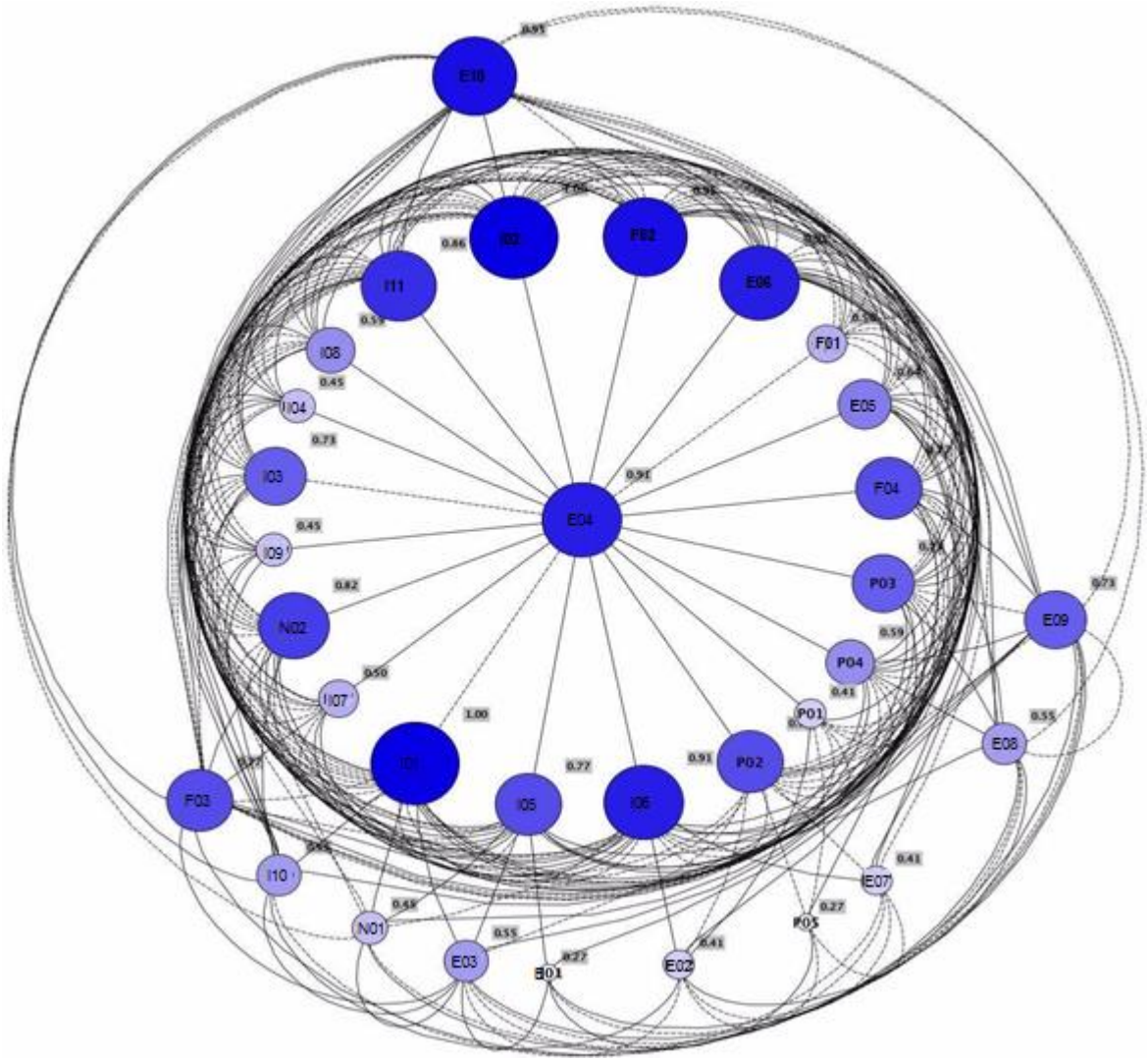
Table 3.

Matrix (relations) of undirected graph

	E01	E02	E03	N01	E04	E05	E06	E07	E08	E09	E10	F01	F02	F03	F04	I01	I02	I03	I04	I05	I06	I07	N02	I08	I09	I10	I11	P01	P02	P03
E01																														
E02																														
E03	2	1																												
N01			2																											
E04																														
E05					2																									
E06	2	2	2	2	2	1																								
E07		1	1				2																							
E08	1	2	1	2		2	2																							
E09	2		2	1			2		1																					
E10				1			2		1	1																				
F01					1	1	1		2		1																			
F02					2	1	1				1	1																		
F03			2			2	2			2	2	1	1																	
F04					2	2	2		2	2	2	1	1	1																
I01			2	2	1	2				2	2		1	1	1															
I02					2	2	2	2		2	2	2	1	1	1	1														
I03				1	1		2				2		1	1		1	1													
I04					2		2									1	1	2												
I05	2		2	2	2				2	2	2		2	1	2	1	1		2											
I06		2		1	2	2		2		2	2		2	2		1	1	2												
I07					2						2		1	2		1	1	1		2	2									
N02				1	2						1		1	2	2	1	1	1	2	2	2	1								
I08					2					2			2			1	2	1	2		2	1	1							
I09					2						1					2	2	2	2	2			1							
I10		2	1			2		1			2		2			2	2						2	2	2					
I11					2	2	2				2	1	2	2		1	2	1	2	2	2	2	1	1	2	2				
P01		2	2		2								2		1						1									
P02		1	1		2		2	1		1	1	1	2		1			1			1						1	1		
P03					2																2							1	1	
P04					2																1							1	1	1
P05		1	1																									1	1	1

Note: The designation of indices and indicators according to table. 1, 2: "1" – a direct econometric relationship is found; "2" – a logical factor relationship is detected

From the 9 indicators, 5 came from the national accounting system, and 4 from international practices that are new to national accounting and monitoring. It is significant that product innovation variables (I01) and (I02) R&D volume are the most significant indicators of the economic development of cluster partnership systems, as shown in *Figure 1*, predetermining the logical and econometric ratios of the population of variables surveyed. However, this is quite expected within the framework of the stated and defining context of the study of clusters structures of the paradigm of "knowledge economics," innovation as a key factor in competitiveness.



Convocation: graph nodes (Table 1, 2); solid line – direct econometric relationship is detected; dashed line – logical factor relationship is detected; inscription next to node – calculated weight in column

Figure 1. An undirected graph of the relationship of indicators and variables, constructed by an incompatibility matrix

But attention would like to focus on 4 indicators new to the national planning and monitoring system. The indicator (P10), which reflects the level of cooperation of subjects with differentiation by elements of the cost structure, is most important and obvious in the context of the study of innovative cooperation. Note that Britton J. N. H. (2003) suggests that it be considered differentiated by all items of the cost of the integrated innovative product of the cluster structure.

In the practice of long-term planning of innovative development, the author proposes to use the cost structure of the anchor production enterprise of the cluster structure as a basis. Based on large cost items (forming 80%), assess the level of intracluster partnership system. This approach most easily and objectively reflects the level of "production" cooperation of cluster partnership systems.

Table 4.

Structure of key indicators of innovative development of cluster partnership systems

Code/gr.	Indicator	Weight of the unit in the column, Fig. 1
I01	Product Innovation	1,00
I02	Amount of R&D performed by CPS entities	1,00

E10	Level of cooperation of entities with differentiation by elements of cost structure	0,95
F02	Investment volume of CPS entities	0,95
E06	"Density" - share of national enterprises of the industry included in the CPS	0,91
E04	Share of exports in gross sales	0,91
I06	Average value added in CPS	0,91
I11	"Knowledge-intensive" CPS - ratio of total costs of the cluster structure for R&D to full turnover	0,86
N02	Amount of OIC acquired by entities within CPS (transfer)	0,82

Note: Compiled by the author

The well-known and popular indicator (I11) "knowledge capacity" (estimated as the ratio of the total cost of a cluster structure for R&D to full turnover) shows its analytical value in competitive comparisons. Known (Porter M., 2005) is the economic relationship (non-linear) of competitiveness and R&D costs, strategically prescribing market parity of research and development costs. And taking into account the factor of global competition, the knowledge intensity index has a logical relationship with the indicator (E 04, %) – the share of exports in the gross volume of sales of CPS. The graph (*Figure 1*) objectively shows that P04 forms the core of the indicator system, expresses the final economic effect of clustering – competitiveness in the global market space. This indicator, which expresses the entrepreneurial aspect of industrial agglomeration, is well supplemented by the variable (P06, %) "density" – the share of national enterprises of the industry included in the cluster structure. Objectively, the increase in the involvement of vertically and horizontally connected enterprises in the innovation cycle (in national and transnational localization) leads to an increase in the economic efficiency of both this cluster structure and the industry.

So, the developed set of 9 indicators is considered as clarifying a solution in the theory of economics, which allows you to set long-term goals for the innovative development of cluster partnership systems and monitor them. The difference between the proposed set and the previously formulated approaches is the validity of the interconnection of indicators and the focus on innovation cooperation.

Conclusions

The set of economic indicators proposed in this section forms an indicative outline of innovative development of cluster partnership systems. In the process of developing the set of indicators, the author formulated several generalizing conclusions and requirements:

1. The existing national structure of indicators is insufficient in terms of variables expressing production cooperation, as well as reflecting the relationship of economic development of cluster partnership systems with the external environment, environment - industries and markets.
2. The rationale for the set of indicators is based on a formalized graph demonstrating logical and econometric relationships.
3. The proposed complex reflects the level of development of scientific, technical and production cooperation, reveals the relationship with local and global markets of innovative products.

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