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Prospects of non-ferrous metallurgy enterprises participation in industrial clusters

Abstract. Formation of industrial clusters network facilitates the competitive potential of territories. Such a development paradigm is defined as the main paradigm among the majority of world countries. This article studies the implementation of clusters in industry, in particular in EU, the impact of clusters on the competitiveness and localisation of areas, as well as the promotion of growth and scientific and industrial potential of the country as a whole.

The article describes the existing prerequisites for the creation of clusters with the participation of non-ferrous metallurgy enterprises. It is shown that currently clustering processes are not being implemented actively enough in the relevant industries, which does not allow us to fully realise scientific and industrial potential of enterprises in the areas of their cluster location.

The analysis of existing methods of industrial clustering has shown the presence of the identification stage with evaluating integration potential of possible participants based on the calculation of specific quantitative indicators for the localisation of clusters - the so called cluster identification procedure. The results of the analysis also make it possible to justify the expediency of choosing the methodology proposed by the National Research University «Higher School of Economics» and the North-West Foundation as a procedure used to identify industrial clusters in non-ferrous metallurgy, which provides the most complete reflection of the functional areas of industrial clusters. The author proposes to apply the specified procedure when calculating concentration indicators such as the personnel potential, high-performance workplaces, innovations which allow estimating the degree of participants' interaction potential in non-ferrous metallurgy, which will increase the number of high-performance workplaces, labour productivity and commercialise scientific and technical developments.

The procedure of identification of industrial clusters in non-ferrous metallurgy, which was supplemented by the author, was used to analyse two already formed clusters of non-ferrous metallurgy enterprises in Chelyabinsk region (implementation of scientific and production processes associated with the extraction of copper ore, production of copper and copper products) and Krasnoyarsk region (aluminium), as well as the cluster already functioning in Sverdlovsk region, associated with titanium products. The results of the research makes it possible to draw a conclusion about the expediency of spreading the above-mentioned «titanium», «copper» and «aluminium» clustering practices in the territorial integration processes in the Russian non-ferrous metallurgy, taking into account the need to enhance innovation.

Keywords: Industrial Cluster; Non-ferrous Metallurgy Enterprises; Cluster Identification; Industrial Cluster Indicators; Non-ferrous Metallurgy Development; Titanium; Copper; Aluminium
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Перспективи участі підприємств кольорової металургії у промислових кластерах

Анотація

Перехід до нової моделі розвитку шляхом формування мережі промислових кластерів, що реалізують конкурентний потенціал територій, визначається як основний серед провідних країн. У статті наведено результати дослідження практики реалізації кластерного підходу в промисловості, зокрема в ЄС, впливу кластерів на показники конкурентоспроможності територій локалізації кластерів, а також стимулювання зростання та реалізації науково-промислового потенціалу країни в цілому.

В роботі описано наявні передумови створення кластерів за умов участі підприємств кольорової металургії. Показано, що станом на цей час процеси кластеризації в зазначеній галузі реалізуються недостатньо активно, що не дозволяє повною мірою реалізувати науково-промисловий потенціал як відповідних підприємств, так і територій локалізації кластерів. Аналіз відомих методик створення кластерів у промисловості показав наявність етапу ідентифікації та оцінки інтеграційного потенціалу їх можливих учасників на основі розрахунку конкретних кількісних показників для території локалізації кластера, тобто процедури його ідентифікації. Результати аналізу дозволили обґрунтувати вибір методики, що була запропонована Національним дослідницьким університетом «Вища школа економіки» та Фондом ЦСР «Північний Захід», для визначення процедури ідентифікації промислових кластерів у кольоровій металургії, що забезпечує найбільш повне відображення функціональних особливостей діяльності промислових кластерів. Зазначену процедуру запропоновано доповнити розрахунком таких показників, як показники концентрації: кадрового потенціалу, високопродуктивних робочих місць та інновацій, які дозволяють оцінити ступінь взаємодії учасників кластерних ініціатив у кольоровій металургії з огляду на кадрове забезпечення, збільшення числа високопродуктивних робочих місць, продуктивності праці й комерціалізації результатів науково-технічних розробок.

Доповнена автором статті процедура ідентифікації промислових кластерів у кольоровій металургії була використана для аналізу двох кластерів підприємств кольорової металургії, що формуються в Челябінській області, й забезпечують науково-виробничі процеси, пов'язані з видобутком мідної руди, виробництвом міді та виробів із міді, й Красноярському краї (алюміній), а також кластера, що вже функціонує в Свердловській області, пов'язаного з виробами з титану. Результати проведеного дослідження дозволили зробити висновок про доцільність використання досвіду функціонування зазначених «титанового», «мідного» й «алюмінієвого» кластерів при реалізації територіально-інтеграційних процесів у кольоровій металургії Російської Федерації з урахуванням необхідності активізації інноваційної діяльності.

Ключові слова: промисловий кластер; підприємства кольорової металургії; ідентифікація кластера; показники промислового кластера; розвиток кольорової металургії; титан; мідь; алюміній.

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Перспективы участия предприятий цветной металлургии в промышленных кластерах

Аннотация
Переход к новой модели развития посредством формирования сети промышленных кластеров, реализующих конкурентный потенциал территорий, определяется как основной среди ведущих стран мира. В данной статье приведены результаты исследования практики реализации кластерного подхода в промышленности, в частности в ЕС, а также влияния кластеров на показатели конкурентоспособности территорий локализации кластеров и стимулирование роста и реализации научно-промышленного потенциала страны в целом.
В статье описаны имеющиеся предпосылки создания кластеров с участием предприятий цветной металлургии. Показано, что в настоящее время в данной отрасли процессы кластеризации реализуются недостаточно активно, что не позволяет в полной мере реализовать научно-промышленный потенциал предприятий, а также территорий локации кластеров.
Анализ известных методик создания кластеров в промышленности показал наличие этапа идентификации и оценки интеграционного потенциала их возможных участников на основе расчета конкретных количественных показателей для территории локализации кластера – процедуры идентификации кластера. Результаты указанного анализа также позволили обосновать целесообразность выбора в качестве процедуры идентификации промышленных кластеров в цветной металлургии методику, предложенную НИУ ВШЭ и Фондом ЦСР «Северо-Запад», обеспечивающую наиболее полное отражение функциональных областей деятельности промышленных кластеров. Предложено указанную процедуру дополнить расчетом таких показателей как показатели концентрации: кадрового потенциала, высокопроизводительных рабочих мест, инноваций, которые позволяют оценить степень потенциала взаимодействия рассматриваемых участников кластерных инициатив в цветной металлургии с точки зрения кадрового обеспечения, увеличения числа высокопроизводительных рабочих мест, производительности труда и коммерциализации результатов научно-технических разработок.
Дополненная автором статьи процедура идентификации промышленных кластеров в цветной металлургии была использована для анализа двух формируемых кластеров предприятий цветной металлургии в Челябинской области (реализует научно-производственные процессы, связанные с добычей медной руды, производством меди и медных изделий) и Красноярском крае (алюминий), а также уже функционирующего в Свердловской области кластера, связанного с изделиями из титана. Результаты проведенных исследований позволили сделать вывод о целесообразности распространения опыта находящихся на разной стадии создания и функционирования указанных «титанового», «медного» и «алюминиевого» кластеров при реализации территориально-интеграционных процессов в цветной металлургии РФ с учетом необходимости активизации инновационной деятельности.
Ключевые слова: Промышленный кластер; предприятия цветной металлургии; идентификация кластера; показатели промышленного кластера; развитие цветной металлургии; титан; медь; алюминий.

1. Introduction

For the first time, sustainable economic communities that can be considered as a cluster due to the concentration of a large number of related organisations in a certain area, as well as the effects of «synergy» and «environment», were highlighted by A. Marshall (2013). M. Porter (1990) defined the main characteristics of the cluster such as the presence of a common raw material base, concentration within the same geographical area, constant technological, commercial and logistical interaction between participants and a fairly narrow professional specialisation, as well as the presence of an innovative component that determines the synergies and provides increased competitiveness of all cluster participants. The implementation of a science-based approach to the formation of the cluster structure of the industry allows us to provide conditions for the development of the territories of their localisation, including the creation of additional high-performance job (Competitive cities in the 21st century: Cluster-based local economic development, 2011).

The consequences of crises, increasing competition and strengthening of the modernisation have led to an increased interest in the use of clusters as proven development tools (European Secretariat for Cluster Analysis, 2012; European Commission, 2016). The development of industrial clusters, often spanning over several related industries, catalyses the economic growth of individual enterprises and regions in order to achieve overall synergies (Feldman, 2014; Delgado, Porter & Stern, 2014). It is also noted that the company which is part of a cluster shows higher performance (Lee, 2018).

Currently, the presence of common logistic flows used by members of an industrial cluster is considered to be the main distinguishing characteristic of an industrial cluster (Shakya, 2009). Another distinctive feature of an industrial cluster is the involvement of enterprises operating within the same value chain (Rosenfeld, 1997). Within a single cluster, enterprises can share information and share common infrastructure elements more easily and quickly.

Special attention to industrial clusters as one of the tools of industrial policy has led to the formation of a system of comprehensive measures of state financial support for the development of cluster formations. As noted in the study of the European Cluster Observatory (European Commission, 2015), the cluster approach is actively used in government programs aimed at developing territories. The stimulation of their formation and development in the Russian Federation is carried out in the framework of Federal Law «On Special Economic Zones in the Russian Federation» No. 116-FZ as of 22 July 2005 (The State Duma, 2005). At the same time, the world experience shows that the transformation of a group of enterprises, connected only by the proximity of their territorial location and common economic interests, into a sustainable cluster is a complex process including the creation of conditions for the formation of an effective system of relations and partnerships (Bode, Talmon l'Armee & Alig, 2010). In this regard, in order to increase the efficiency of the use of resources (including state budgets of various levels) spent on the clustering of industry, it is necessary to solve two interrelated tasks. Firstly, it is necessary to assess the feasibility of creating clusters with the participation of backbone enterprises of various industries, which includes, for example, non-ferrous metallurgy. Secondly, it is necessary to select and adapt the existing procedures for the identification of industrial entities and other economic entities as a cluster, taking into account the specifics of economic activities and the need to ensure the most complete reflection of functional areas of industrial clusters in the field of innovation.

2. Prerequisites for the creation of industrial clusters based on non-ferrous metallurgy

Non-ferrous metallurgy is a key sector of the industrial complex of many developed countries and regions with significant export potential. For example, in 2017, metals and metal products exported from Russia equalled USD 35.9 billion dollars (Federal Customs Service of the Russian Federation, 2018). At the same time, it should be noted that Russian

mainly exports mainly primary processed products, while non-ferrous metal products with high added value are even imported for some items. Taking into account this circumstance, one of the possible scenarios for improving the economic efficiency of the Russian industry is the transition to the production of products with high added value on the basis of closer integration of enterprises, such as those which produce ore raw materials, enterprises relating to other industries, as well as research, engineering and educational organisations. It is obvious that the greatest effect of this integration can be obtained with the territorial localisation of data of economic entities and implementation of a common system of management of interrelated logistics flows within the industrial cluster.

A significant part of European regions have historically developed certain specialisations reflecting their unique strengths. Therefore, German regions are strong in terms of production technologies of metallurgical and chemical industries. Northern regions of Europe are more specialised in engineering and transport. Production of non-ferrous metals in Europe is a large sector of industry, which employs about 500,000 people. The total annual turnover of enterprises of this type activities amounted to about EUR 120 billion in 2010.

Non-ferrous metal production accounted for 1.25% of the EU production in 2010 (European Commission, 2018). Based on the contribution of the industry to the industrial sector in European countries, we can single out the following countries in descending order: the Czech Republic, Slovakia, Slovenia, Germany, Italy, France, Belgium, Finland, Poland, Spain, Sweden and Switzerland. Also, it is necessary to note a particular feature of the location of the regions of specialization: the successful development of enterprises engaged in the production of high-tech products and the active introduction of new approaches is implemented in sectors experiencing a shortage of natural resources. In addition, some of the European clusters can be called cross-border entities, as they include enterprises of several European countries. For example, twenty is located in the Dutch-German border region. The largest European clusters specialising in metallurgy are presented in Table 1.

The analysis of the world trends in the development of non-ferrous metallurgy suggests that at present there is a change in the paradigm of the use of metals. An increase in production volumes only can no longer meet the needs of industrial enterprises. With a steady increase in demand, producers must move beyond traditional advantages, since high-value-added products mainly provide long-term competitive advantages to modern industrial enterprises.

The Analysis of the state and prospects of development of Russian non-ferrous metallurgy allows identifying the following prerequisites for the creation of industrial clusters on their basis:

1. There is a possibility of activation of innovative processes aimed at the coordination of all participants in the chain «extraction of raw materials - production of nonferrous metals - production of nonferrous metals» in the creation of new resource-saving technologies and expanding the range of high-tech products with high added value within the industrial cluster.
   This will make it possible to reduce the gap in the results of patenting between domestic and foreign enterprises of non-ferrous metallurgy (currently, for example, the American transnational corporation Alcoa has a patent portfolio of more than 4,500 objects of intellectual property, in the rate of patenting around 30 patents a year, whereas the largest Russian aluminium producer UC Rusal is the owner of only about 100 patents (Patent Information Portal Orbit, 2018).
2. In a number of regions hosting large domestic non-ferrous metallurgy enterprises of the Russian Federation, there is a significant production potential and developed infrastructure for the formation of clusters based on the use of favourable transport and geographical location, territorial proximity of consumers and the availability of training and retraining centres.
3. Protectionism of a number of leading foreign countries (primarily the United States) in the world market of non-ferrous metals determines a need for the development and implementation of state support measures for the industry, targeting, consistency and validity of which depend on the degree of integration of domestic non-ferrous metallurgy enterprises with each other and with other participants in creating added value in the production of final products;
4. There is a positive foreign and domestic experience in the creation and development of industrial clusters, for example, the Hessenmetall aviation cluster, located in Germany in the Rhine-main metropolis and specializing in the production of metal products for the aviation industry, the innovative territorial titanium cluster of Sverdlovsk region, etc.

The observed trends in the development of the Sverdlovsk titanium cluster (the volume of innovative products shipped by its participants of their own production, innovative works and services performed on their own, increased from RUB 5.6 billion to RUB 11.6 billion; the number of high-performance workplaces created as new or as a result of modernisation of existing jobs was from 40 units to 650 units; the average output per employee of the cluster member was from Rub 2.5 million per person to RUB 3.1 million per person annually in the period between 2013 and 2017) allow us to draw a conclusion about high efficiency of this initiative.

The presence of these prerequisites has led to a situation when a number of non-ferrous metallurgy enterprises attempted to form cluster formations. The Russian Copper Company, located in Chelyabinsk region, is planning to create a copper cluster with the assistance of the administration of Chelyabinsk region by 2021. It will produce not only the extraction and enrichment of copper ore, but also copper cathode, copper electrolytic foil, commercial salts of cobalt, nickel sulphate (including oxidised Nickel concentrates) and other copper products for industrial and domestic purposes, which will be an additional catalyst for the development of the economy of the territory (Russian copper company investments in the economy of the Southern Urals more than 120 billion rubles, 2018). The proximity of the city agglomeration of Magnitogorsk, the largest metallurgical innovation centre in Russia, should be considered to be an additional success factor for the creation of this cluster. Also, we should note the project on the creation of the Krasnoyarsk technological valley in Krasnoyarsk region - an aluminium cluster initiated in 2016 by the

Tab. 1: **European clusters specialising in the field of metallurgy**

No.	Cluster name	Number of employees	Country
1.	Lombardia	166,590	Italy
2.	Arnsberg	118,659	Germany
3.	Düsseldorf	91,038	Germany
4.	Veneto	69,847	Italy
5.	Rhône-Alpes	69,727	France
6.	Stuttgart	69,044	Germany
7.	País Vasco	65,442	Spain
8.	Espace Mittelland	52,310	Switzerland
9.	Moravskoslezsko	51,741	Czech Republic
10.	Freiburg	45,351	Germany
11.	Slaskie	44,713	Poland
12.	Slovenija	43,984	Slovenia
13.	Danmark	40,283	Denmark
14.	Vlaams Gewest	38,879	Belgium
15.	Sud-Est	36,040	Romania
16.	Stredni Morava	22,310	Czech Republic
17.	Vychodne Slovensko	35,897	Slovakia
18.	Östra Mellansverige	28,708	Sweden
19.	Norra Mellansverige	22,167	Sweden
20.	Stredne Slovensko	21,808	Slovakia
21.	Zapadne Slovensko	20,956	Slovakia
22.	Småland med öarna	16,359	Sweden
23.	Pohjois-Suomi	8,859	Finland

Source: Compiled by the author based on data of *«Innovation clusters in Europe. A statistical analysis and overview of current policy support»* by European Commission (2008)

Aluminium Association and UC Rusal (Krasnoyarsk technological valley, 2017).

These prerequisites determine the feasibility of further measures for the implementation of the state cluster policy in non-ferrous metallurgy based on the use of modern scientifically based tools.

3. Analysis of the modern methodological apparatus for assessing the feasibility of the formation of industrial clusters

Given the diversity of the concept of «industrial cluster», it can be noted that a single value chain, horizontal and vertical integration, common interests of the participants of this integration formation cannot be the final markers of the feasibility of clustering. As a result, all methods of forming clusters (see Timothy, 2016; Polozhentseva & Klevtsova, 2015) include the stage of identification and evaluation of the integration potential of possible participants based on the calculation of specific quantitative indicators to areas of localisation in the cluster (TLC).

Active work on the identification of clusters and their quantitative assessment for the formation of regional development strategies, clarification of directions and forms of state support, evaluation of already implemented activities in the field of regional policy, coordination of positions of various cluster members and methods of their management have been carried out in the United States since the late 1990s (Porter, 2003; Brenner, 2006; Duranton & Overman, 2005). The analysis of existing approaches to the determination of the potential of formed clusters is presented in (Kutsenko, 2009). Cluster identification methods can be divided into qualitative and quantitative methods. The use of expert-based qualitative methods raises problems of subjectivity, the complexity of verification of the results and the scaling of research (Danko & Kutsenko, 2012). In foreign practice (OECD, 1999), quantitative methods based on the analysis of inter-sectoral balances at various levels are most often used to identify clusters.

In the authors' opinion, from the point of view of objectivity and completeness of the available information, it is advisable to use the methodology proposed by the HSE and the North-West Foundation (2014) in their Report «Management System for Managing Companies of Innovative Territorial Clusters of the Russian Federation» adapted to the peculiarities of business processes in non-ferrous metallurgy to identify potential industrial clusters, and assuming the calculation of the following indicators.

Confinement factor for the share of employed (LQ):

$$\mathrm{LQ} = \frac{Emp_{ig}}{Emp_g} \Big/ \frac{Emp_i}{Emp}, \quad (1)$$

where:

Emp_{ig} - the number of employees in non-ferrous metallurgy on TLK g;

Emp_g - the total number of employees on TLK g;

Emp_i - the number of employees in non-ferrous metallurgy in Russia;

Emp - the total number of employees in Russia.

This indicator was proposed in the Lindqvist (2009) methodology and the methodology of the European Cluster Observatory (Sölvell, Ketels & Lindqvist, 2008) with a threshold value for assigning groups to significant cluster groups in the region ≥ 2. The determination of significant cluster groups based on the calculation of the localisation coefficient (LQ) can be carried out on the basis of open statistical data (Billings & Johnson, 2012).

2. Revenue localisation ratio (LR):

$$\mathrm{LR} = \frac{R_{ig}}{R_g} \Big/ \frac{R_i}{R}, \quad (2)$$

where:

R_{ig} - the revenue of the enterprises of non-ferrous metallurgy on $TLK\ g$;

R_g - the total revenue of all enterprises in $TLK\ g$;

R_i - the total revenue of all enterprises of non-ferrous metallurgy of the Russian Federation;

R - the total revenue of all industrial enterprises in Russia.

This indicator was proposed by M. Porter (2003) who determined that the industry prevails in the region with a value of more than 1. In later studies, the specified index for the cluster is considered to be ≥ 2.

3. Herfindahl-Hirschman index (HHI):

$$HHI = \sum_{i=1}^{n} \left(\frac{R_{ign}}{R_i} \right)^2, \quad (3)$$

where:

R_{ign} - the revenue in the company n non-ferrous metallurgy on $TLK\ g$;

R_i - the total revenue of all enterprises of non-ferrous metallurgy;

n - the the number of the enterprises of non-ferrous metallurgy in Russia.

The Herfindahl-Hirschman index is one of the main indicators of the level of concentration of enterprises in the industry. According to (Rastvortseva, 2017), its values are in the range from 0 to 1, while the proximity to 1 characterises the degree of concentration of production.

4. The coefficient of inventive activity TLK - EA / 10 thousand population (P):

$$P = \frac{10000 \cdot N}{C}, \quad (4)$$

where:

N - the number of applications filed per year for the grant of a patent for inventions and utility models on $TLC\ g$;

C - the population on $TLC\ g$ in that year.

5. The index of acquisition is determined by the method described in (Dadov, 2012) on the basis of the matrix of inter-industry balance and characterises the degree of development of relationships of those industries that are represented in TLC. Due to the fact that inter-sectoral balances between countries and regions are not always presented in official statistics, the calculation of this indicator for clusters in non-ferrous metallurgy is quite difficult.

In turn, on order to assess the degree of clustering, the author of the article proposed to additionally calculate the following indicators, reflecting the degree of interaction of the main participants in the formation and operation of industrial clusters in non-ferrous metallurgy, as well as allowing to take into account significant factors identified in (Kutsenko, 2012) when adapting the model of Lindqvist in relation to the Russian practice of industrial development.

6. Concentration of human resources (H):

$$H = \frac{S_{ig}}{S_g} \Big/ \frac{S_i}{S}, \quad (5)$$

where:

S_{ig} - the number of students of cluster universities in the areas of training related to non-ferrous metallurgy in $TLK\ g$;

S_g - the number of all students at $TLK\ g$;

S_i - the number of students in the areas of training related to non-ferrous metallurgy in Russia;

S - the total number of students of all universities in Russia.

7. The measure of concentration In the RM (RP):

$$RP = \frac{ВПРМ_{ig}}{ВПРМ_g} \Big/ \frac{ВПРМ_i}{ВПРМ}, \quad (6)$$

where:

$ВПРМ_{ig}$ - the number of high-performance jobs (HPJ), re-created or being the result of modernisation of existing jobs with the companies of the cluster g;

$BIIPM_g$ - the number of HPJ, re-created or being the result of the upgrade of existing jobs businesses in $TLK\,g$;

$BIIPM_i$ - the number of HPJ, re-created or being the result of modernisation of the existing jobs of the metallurgical enterprises of the Russian Federation;

$BIIPM$ - the total number HPJ, re-created or being the result of modernisation of the available jobs in the industry.

8. The rate of localisation of innovation (IV):

$$IV = \frac{V_{ig}}{V_{ig}} / \frac{V_g}{V_g}, \quad (7)$$

where:

V_{ig} - the volume of innovative goods, works and services of cluster g enterprises in value terms;

V_g - the volume of innovative goods, works and services in value terms in $TLC\,g$;

V_i - the volume of innovative goods, works and services in value terms of all metallurgical enterprises of the Russian Federation;

V - the total volume of innovative goods, works and services in value terms in the Russian industry.

It is obvious that the threshold value of the proposed indicators (5)-(7), which allows attributing cooperative education on the basis of non-ferrous metallurgy to an industrial cluster, is 1. Given that to clarify these values, it is necessary to conduct long-term observations of the development of industrial clusters of the industry in question to obtain a representative sample for analysis (for example, by analogy with the studies by M. Porter (2003), as a benchmark, we can consider their values calculated for the successfully developing Sverdlovsk titanium cluster.

4. Identification of functioning and forming clusters in non-ferrous metallurgy

Based on the calculation of the values described in the previous section of the supplemented set of indicators, we carried out the identification of the Sverdlovsk titanium cluster functioning since 2012, as well as the formed Chelyabinsk copper and Krasnoyarsk aluminium clusters. The calculated values of indicators (1) - (7) for these clusters are given in Table 2.

Tab. 2: **Indicators for identification of clusters in non-ferrous metallurgy**

Cluster \ Indicator	LQ	LR	HHI	P	H	RP	IV
Krasnoyarsk aluminium cluster	5.65	3.94	0.18	0.74	1.48	n/a	n/a
Chelyabinsk copper cluster	6.73	4.86	0.11	0.99	1.6	n/a	n/a
Sverdlovsk titanium cluster (2012)	12.06	7.24	0.45	2.29	1.38	1.92	1.18
Sverdlovsk titanium cluster (2017)	14.20	10.88	0.48	1.79	1.42	2.76	1.17

Source: Compiled by the author based on (Industrial Production, 2018) and data from the reporting of non-ferrous metallurgy

As it can be seen from Table 2, the calculated values of indicators LQ, LR, HI and H allow us to refer the considered formations to industrial clusters. The increase in the values given in Table 2 of the indicators (except P and IV) of the Sverdlovsk titanium cluster in the period 2012-2017 testifies to its successful development, which makes it possible to recommend the dissemination of this positive experience in the implementation of the cluster approach, based on the model of territorial localisation of the intermediate links of the chain «titanium production - production of final products» (Gokhberg & Shadrin, 2015).

At the same time, the value of the coefficient of inventive activity P for 2017 for the two potential aluminium and copper clusters under consideration is lower than in the Russian Federation as a whole (2.24), which indicates that there is still an insufficient level of interaction between non-ferrous metallurgy enterprises and innovation infrastructure organisations. This is also evidenced by a decrease in the value of P from 2.29 to 1.79 and the value of IV from 1.18 to 1.17 for the functioning Sverdlovsk titanium cluster for the period between 2012 and 2017. This trend determines the expediency of increasing attention from the coordination structures of clusters, as well as public authorities in the selection of control incentive measures for the development of clusters with the participation of non-ferrous metallurgy. As one of the ways to solve the problems of increasing the innovative activity of cluster formations in non-ferrous metallurgy, the network model of the organisation of transfer of innovative technologies can be considered.

5. Conclusions

The results presented in this article allow us to draw a conclusion about a sufficiently high potential of cluster formation in the non-ferrous metallurgy of the Russian Federation with insufficient active implementation of this process, which does not allow the full use of resources in the areas of localisation of clusters.

When assessing the feasibility and monitoring the implementation of the process of cluster formation, the role of the procedure of their identification increases, which is an integral stage of the known methods of creating territorial integration formations in the industry. It is obvious that this procedure should include a set of quantitative indicators, the calculation of which should be carried out on the basis of objective and accessible information that most fully characterizes the most important aspects of the cluster.

Taking into account this fact, to identify clusters in non-ferrous metallurgy, it is proposed to supplement the set of indicators proposed by the National Research University «Higher School of Economics» and the North-West Foundation with indicators of the concentration of human resources, high-performance jobs, as well as the results of innovation activities in the analysed cluster. This set of indicators should be used to improve the validity of decisions on the formation and promotion of industrial clusters in non-ferrous metallurgy at the Federal and regional levels.

The supplemented set of indicators is used to identify two clusters of non - ferrous metallurgy enterprises - the Chelyabinsk copper and the Krasnoyarsk aluminium clusters, as well as the already functioning Sverdlovsk titanium cluster. The results of the analysis showed that these cluster initiatives in the field of non-ferrous metallurgy meet the conditions of formation of stable cluster formations in terms of most of the indicators. At the same time, the importance of the degree of concentration of innovation results and the level of inventive activity for the clusters under consideration indicates the need for closer attention to these important aspects of cluster development in non-ferrous metallurgy.

The obtained results allow us to make a conclusion about the expediency to draw on the experience of the processes of creation and functioning of these «titanium», «copper» and «aluminium» clusters in the implementation of territorial integration processes in the non-ferrous metallurgy of the Russian Federation, taking into account the need to increase attention to the issues of improving the efficiency of innovation.

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