Economic Transformation of a Mining Territory Based on the Application of a Cluster Approach

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The economic aspects of the transformation of the mining industry and spatial development in the city of Berezniki, Perm Region (Russia) are analyzed in the article. A quantitative assessment of inter-sectoral relations within the framework of the economy of a mining city is given. The results of economic and mathematical modelling of the creation of a territorial industrial cluster based on a mining enterprise are presented. The purpose of the study is to calculate changes in the economic development of a single-industry city and a municipal district when an industrial cluster is created on its territory with a mining enterprise as the core of a cluster (the flagship of the municipal economy). When applying the cluster approach, the emphasis was placed on the leading position of the mining enterprise in a specific territory, its role in the development of the economy of the single-industrial city and the municipality was assessed. The result of the study is a quantitative assessment of the effectiveness of creating an industrial cluster in the single-industrial city of the mining industry. It is proved that when forming a cluster around the existing mining enterprise, it is possible to obtain a high positive effect from the cluster for urban and municipal development.

Keywords: *Mining industry, sustainable development, economic and mathematical model, the cluster model*

Introduction

ñIndustrial cluster and enterprise agglomeration is industrial upgrading model of the high-end and most competitive advantage in the world todayò (*Le and Ning*, *2015*, *tc.1879*). One of the key policies in economic development to move towards becoming a country with global competitive potential is to promote cluster development. A ñclusterò is a powerful tool and mechanism for enhancing competitiveness and the development of an industrial economy in a country (*Fongsuwan*, *2017*). This is fully consistent with the strategic objectives of the development of the territory with a predominance of extractive industries. This is especially important for territories with a single city-forming enterprise, on whose activities the well-being of entire large territories and cities depends. «Improvement of the economic activity of industrial companies determines conditions for the possible improvement of mining and metallurgical business activity and finds the sources of companiesô growth» (*Manová et al.*, *2018*, *p.132*).

Creating a more efficient economy is achieved on the basis of constant change. For the former socialist countries, «On example of such change is a transformation process from a centrally planned economy to market economy» (an example of such a change is the process of transition from a centrally planned economy to a market economy) (*Budaj et al.*, *2018*, *p.1*). In our study, we consider a transformation process as a process of changing the mechanism of interaction between enterprises of different sectoral affiliations operating within the limited framework of one mono-specialized territory - the mining area. Cluster association is the basis of this change and its result.

The theory of industrial clusters in the modern sense was developed from the works written by M. Porter. Porter M. determined that a cluster is a group of enterprises and related organizations involved in the same case with cooperative linking and addition (*Porter*, *1998).* The expediency of creating a cluster is explained by the fact that "When considering success for the industry in developed or developing countries, it is apparent that successful industries do not come from a single company or entity alone. Instead, it comes from multiple ventures competing in clusters, resulting in sustainable economic growth (*Fongsuwan*, *2017*).

One of the key factors for the success of this network development mechanism is the distribution of financial benefits for the business (*Martin and Sunley*, *2002).* In turn, business in a cluster is often stimulated to increase efficiency, stimulate research and development, and increase business efficiency (*Porter*, *2011).*

The activity of clusters leads to the creation of a more efficient regional economy, on the basis of obtaining by all enterprises in the region sustainable and high profits.

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Previous research also has proved, that by organizing cluster interaction and coordinating with industry member colleagues, smaller firms strengthen their competitive profile (*Lechner and Dowling, 2003*) and increase their chances of survival (*Hoang and Antoncic, 2003*).

The much positive impact on the development of the regional (municipal, urban) economy is enhanced if the industrial cluster is transformed into a technology park structure - i.e. in addition to purely industrial enterprises includes scientific centres and laboratories, educational institutions, business incubators, start-ups and other innovation infrastructure objects (*Pascu et al., 2013; Shaidurova, 2017; Mingaleva and Shaidurova, 2018*).

Numerous and diverse studies have explained many trends and issues of cluster development (Hervás-Oliver *et al., 2015; Trippl et al., 2014; Yu et al., 2015)*. The recommendations have been developed on the creation of industrial clusters (*Feser and Bergman, 2000*), their development (*Le and Ning, 2015).* A number of studies provide estimates of the role of clusters in national and world development (*Lindsay, 2005; Hsu et al., 2013*), in innovative development (*Lesnik and Mingalyova, 2013*), in creating research and development (Lechner and Dowling, 2003; *Ma Ding, 2014*) and a number of other economic processes (*Bengtsson and Sölvell, 2004; Zhu, 2003*). And these studies are not stopped but are supplemented with new data and take into account new trends and phenomena, including at the regional and municipal levels (*Mingaleva et al., 2017*).

The importance of industrial clusters for regional and municipal development is also noted in the most recent studies (*Kusa et al., 2019*). Thus, in the work of Sergey Anokhin, Joakim Wincent, Joakim Wincent, Vinit Parida, Natalya Chistyakova and Pejvak Oghazi the increasing role of industrial clusters for the development of the region is noted, since they are becoming significant positive predictors of innovation dynamics at present (*Anokhin et al., 2018*).

As for the creation of clusters in the mining industry or on the basis of a large extractive enterprise, at the present time, there are very few such studies. Basically, this is the study of such cluster development issues as the role and importance of the extractive industry as a whole for the national economy of specific countries (*Budaj et al., 2018).* In this case, the question of the feasibility of creating a cluster may be associated with the need to increase the competitiveness of the industry. Thus, it is particularly noted that in a number of countries "given the high level of mining costs and the cost of processing domestic ore raw materials, their mining is uneconomical" (*Budaj et al., 2018, p.3*). And the cluster could help.

The functioning of individual mining and extractive enterprises, including the environmental damage that these enterprises create, and environmental problems, are investigated (*Biağy 2014*; *Biağy & Mroczkowska, 2015)*. It is noted that in a number of countries, domestic resources of certain types of minerals (coal, shale, peat, etc.) are considered as a strategic resource base, reducing dependence on imports of primary fuel and energy raw materials, as well as ñreserves for unforeseen situations and as a source of employment opportunities"(*Budaj et al., 2018, p.3*). Also, a number of works are devoted to the creation of clusters in a low-carbon economy (*Zhang, 2016*).

Material and Methods

Method

The simplest and economically significant is the application of the cluster's methodology for cities with one or several city-forming enterprises. On the one hand, in such cities, there are a limited number of enterprises - the poles of economic growth, which simplifies the assessment and prioritization in determining the boundaries of clusters on the values of multipliers. On the other hand, it becomes easier to evaluate the synergistic effects obtained from the coordinated work of cluster members. By UNCTAD methodology the countries in which the share of mining and processing of raw materials in the gross domestic product (GDP) is more than 25% are classified as countries with the developed mining industry (*Budaj et al., 2018*). We extrapolated this methodology to the regional level and identified Berezniki as a city with a developed mining industry because the mining and chemical industries provide almost 90% of the industrial activity of the city. Based on the above, we consider the practical application of the author's developed methodology with reference to the industrial complex of the city of Berezniki, Perm Region of the Russian Federation, specialized in the mining of potash deposits and the production of mineral fertilizers.

The methodological approach to the selection of enterprises in a cluster takes into account that a cluster is a mutually dependent grouping that focuses on the real participation of all sectors (*Sölvell et al., 2003*). Therefore, we have included in the cluster all enterprises of different branches of production and material services operating in the city of Berezniki. In accordance with the methodology based on the available data of the Federal State Statistics Service of the Russian Federation according to the tables ñCosts - outputò in monetary terms for 2015 (*National Accounts, 2015, downloaded on 30. August 2018, available online:* www.gks.ru/wps/wcm) we identified possible options for building a technological chain of interconnection between the industrial enterprises located in the city Berezniki, Perm Region of the Russian Federation. Cluster vertical links unite business operators in ascending or descending technological lines, and horizontal links connect various auxiliary industries designed to achieve common goals. ñThe businesses in the group are often stimulated to increase efficiency, promote research and development and improve business performanceò (*Porter, 2011).*

In the process of selecting industries and enterprises to build a technological chain in a cluster, we took into account the characteristics of the life cycle of technologies and their role in the viability of the cluster (*Dalum et al., 2005*) and the need to fill gaps and more precisely establish specialization in extended product chains (*Feser and Bergman, 2000*). We also took into account the impact of structural changes between sectors on the economic security of the territory where enterprises united in a cluster *(Mingaleva and Gataullina, 2012).*

An important feature of the cluster, which has been noted by many researchers, is its ability to coordinate supply chains (*Kristal et al., 2010)*. And different industries and countries occupy different places in these chains. For example, studying the place and role of Chinese enterprises in global clusters showed that Chinese are ñmost of the cluster in the global value chain in the low middle value added production processing link..." (*Le and Ning, 2015, р.1879*). Le and Ning explain why most Chinese industrial clusters are still "at the lower end of the road in the development of industrial clusters" by this fact (*Le and Ning, 2015, р.1879*).

In our methodology, we used the results of the research of Ma Ding (*Ma Ding, 2014*), who investigated the collaboration in the supply chain and possible additional benefits from such collaboration. In particular, he wrote that the collaboration in the supply chain could work together in creating research and development.

Currently, science has already developed and applied methods for analyzing the efficiency of industrial clusters adapted to the requirements of the information economy and digitalization. For example, S. Papagiannidis, E.W.K. See-To, D.G. Assimakopoulos and Y. Yang, presented a methodology for big data analytics, which can be utilised as a decision support system for identifying industrial clusters in a specific geographic region (*Papagiannidis et al., 2018, p.355*). The proposed methodology was tested on the example of industrial clusters in the North East of England and showed good and accurate results with a large database.

The proposed methodological approach was used by us to develop the author's methodology for transforming the mechanism of interaction between enterprises operating within a specific territory in order to create an industrial cluster. The database consists of the data from the Federal State Statistics Service of the Russian Federation (ROSSTAT database). The main methods of applying statistical data for modelling the cluster we took from Hartigan 's work (*Hartigan, 1985*).

The database

The city Berezniki, Perm Region of the Russian Federation is an industrial city with most mining and processing companies in the chemical industry. Berezniki is characterized by an excessive concentration of industrial potential. There are many enterprises of heavy industry, its basic industries. The structure of industrial production of Berezniki is given in Table 1.

Tab. 1. The structure of industrial production of Berezniki city

The industry sector	The industry share in the fixed assets	The industry share in the industrial output of Berezniki
The chemical complex	87.3%	79.2%
The fuel and energy sector	8.2%	8.8%
The complex for the production of consumer goods	1.0%	6.7%
The mechanical engineering	1.6%	1.2%
Other industries	3.0%	4.1%

Source: own processing

Several enterprises that are official monopolists in Russia work in Berezniki. These are:

- "AVISMA" branch of PSC "VSMPO-AVISMA Corporation" (it produces the titanium sponge and titanium powders, metallic magnesium, magnesium alloys and products, chemical products, that are sold not only in Russia but throughout the world);
- ñAzotò branch of OJSC ñURALCHEMò (it produces the ammonium nitrate, carbamide and other nitrogenous fertilizers);
- PJSC Uralkali, which has in the city 2 Potash Production Mine Administration (BKPRU) ï BKPRU-1 and BKPRU-4 (it produces the potash fertilizers).

Berezniki is an important transportation hub: the main automobile road Perm-Solikamsk passes through the city, going further to the north of the Perm Territory. Also in Berezniki, there is water transport communication on the Kama River. At the present time, the railway is being restored, which was destroyed by a failure at the mine BKPRU-4 PJSC Uralkali.

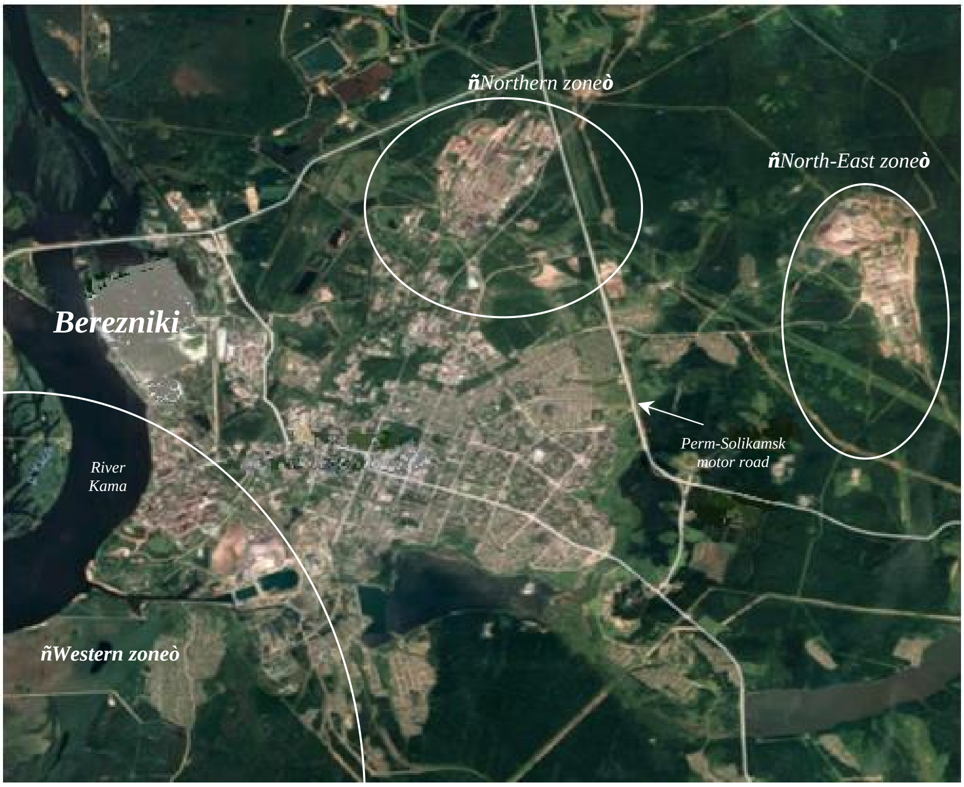
All industrial enterprises located in the city Berezniki, Perm Region of the Russian Federation are united in 9 groups. The name of these groups, their conditions number for the econometric calculations and their correlation with Russian Classification of Economic Activities (OKVED) are given in Table 2. In our methodology, we take into account conclusions about the limitations of the Standard Industrial Classification (SIC) codes, which are manifested in the digital economy (*Papagiannidis et al., 2018; Bako, 2016*).

Tab. 2. The clustering of enterprises in accordance with the Russian Classification of Economic Activities

The industry sector of enterprises	**Identification by Russian Classification of Economic Activities (OKVED codes)**	**Reference numbers for the calculations**
The production of potash fertilizers	Section C - "Manufacturing": 20.15.5 - Subgroup "Production of potash mineral or chemical fertilizers"	1
Fuel production	Section C - "Manufacturing": Class 20 ï ñManufacture of chemicals and chemical productsò	2
Manufacture of machinery and equipment	Section C - "Manufacturing": Class 28 - "Manufacture of machinery and equipment not included in other groups": Subclass 28.1 - "Manufacture of machinery and equipment for general use."	3
Electricity and heat supply services	Section D - "Provision of electric energy, gas and steam; air conditioningò: Subclass 35.30 ï ñProduction, transmission and distribution of steam and hot waterò; Subclass 35.1 - "Production, transmission and distribution of electricity."	4
Construction work	Section F ï ñConstructionò: Class 41 ï ñBuilding constructionò; Class 43 ï ñSpecialized construction worksò.	5
Wholesale trade services	Section G ï ñWholesale and retail tradeò: Class 46.1 ï ñTrade on a fee or contract basisò	6
Land transport services	Section H ï ñTransport and storageò: Class 49 ï ñActivity land and pipeline transportò	7
Services of water transport organizations	Section H ï ñTransport and storageò: Class 50 ï ñWater transport activitiesò.	8
Production of other goods and services	A cumulative group including multiple identification codes	9

Source: own processing

The territory of Berezniki can be divided into 3 industrial zones, where the main enterprises are concentrated. The map of Berezniki where these 3 industrial zones are indicated is shown in Figure 1.



Source: own processing

Fig.1. The main industrial zones of Berezniki

Figure 1 shows the following industrial zones formed by monopolistic enterprises in the mining and chemical industries:

- ñNorthern zoneò (the enterprises of ñAVISMAò branch of PSC ñVSMPO-AVISMA Corporationò);
- ñNortheast zoneò (the mines and enterprises of ñBKPRU-4 PJSC Uralkaliò)
- ñWestern zoneò (the mines and enterprises of ñBKPRU-1 PJSC Uralkaliò, ñOJSC Azotò, ñOJSC Berezniki Soda Plantò; ñJSC Berezniki Mechanical Plant" and other enterprises).

The ñNortheastò and ñWesternò zones were chosen as the basis for building the cluster model. Uralkali is the flagship enterprise in these zones.

The database consists of the data on the according to the tables ñCosts - outputò in monetary terms, the data on the industry sector of enterprises, the price data for major industrial products, the inflation data and other statistics.

In total, over 2000 enterprises and organizations of all sizes and forms of ownership were taken for calculations. These enterprises employ more than 40,000 workers.

The accounting and economic indicators of the main enterprises included in the technological chain of the proposed cluster are given in Table 3 (*Three **ñ**whales**ò**, 2017*).

Tab. 3. The accounting and economic indicators of the main enterprises of the city of Berezniki [rubles]

Place	*Name*	*Income*	*Profit (loss) before tax*	*Balance sheet*	*Non-current assets*	*Current assets*	*Capital and reserves*
3	PJSC Uralkali	131 311 916	80 911 970	630 367 555	522 332 297	108 035 258	168 086 315
26	LLC "Uralkali-Repair"	7 119 963	450 330	3 489 542	158 406	3 331 136	928 088
36	JSC "Bereznikovsky Soda Plant"	5 595 832	650 740	4 534 741	3 800 879	733 862	2 359 271
84	LLC "Soda-chlorate"	2 427 754	-633 816	4 089 511	3 560 425	529 086	612 511
156	CJSC "Bereznikovskaya network company"	1 384 436	-346 588	1 154 265	235 262	919 003	-497 345
160	Azottech LLC	1 347 591	81 723	271 399	106 852	164 547	192 137
180	LLC "Construction company "Himspetsstroy"	1 126 940	23 288	517 128	215 183	301 945	66 827
234	JSC Berezniki Mechanical Plant	803 913	5 017	1 714 527	472 550	1 241 977	32 346
246	LLC "AVISMA-Spetsremont"	751 364	32 880	376 592	2 526	374 066	40 472

Source: own processing

Table 3 shows the enterprises in the order of ranking places that they occupied in the TOP-300 of the largest enterprises of the Perm Krai (*TOP-300*). This rating is compiled in terms of revenue from the sale of goods, products, works and services.

Results

To solve the research task, under the transformation process, we understand the process of uniting enterprises of various industries that exist in a specific mining area in order to create a territorial (urban) multi-sectoral cluster. Determining the possibilities of organizing a regional cluster in Berezniki began with the choice of a market for end products, in which the flagship enterprise has an advantage in price or quality of goods. This will need to put pressure on the market at the expense of jointly organized shares of cluster members. The choice of the flagship enterprise is also important from the point of view of organizing the technological chain and network of interactions in the cluster. In accordance with the author's methodology, in the beginning, we calculated the coefficients of the total costs for each industry sector of enterprises. These coefficients obtained by the "Cost-output" model (*National Accounts, 2015, downloaded on 30. August 2018, available online:* www.gks.ru/wps/wcm) and characterizing the full standard of costs for the purchase of intermediate goods and services of the enterprises - suppliers, located in the ***i***-th lines of the table for the production of the monetary unit of the benefit of enterprises ï consumers indicated in the ***j***-th columns. The coefficients of the total costs present in Table 4.

Tab. 4. Coefficients of total material costs and the rate of value added by types of economic activity per monetary unit of finished goods

The numbers of industry sector	1	2	3	4	5	6	7	8	9
1	1,0135	0,0004	0,0006	0,0005	0,0124	0,0005	0,0020	0,0006	0,0000
2	0,0689	1,1519	0,0136	0,0356	0,0331	0,0261	0,0752	0,1744	0,0000
3	0,0557	0,0066	1,1647	0,0107	0,0216	0,0067	0,0134	0,0291	0,0000
4	0,0727	0,0333	0,0378	1,5542	0,0139	0,0193	0,0645	0,0192	0,0000
5	0,0182	0,0070	0,0060	0,0188	1,0288	0,0067	0,0186	0,0098	0,0000
6	0,0448	0,0413	0,0876	0,1866	0,0638	1,0391	0,0312	0,0408	0,0000
7	0,0627	0,1550	0,0541	0,0718	0,0416	0,2301	1,1949	0,1132	0,0000
8	0,0376	0,0023	0,0008	0,0008	0,0026	0,0019	0,0032	1,0234	0,0000
9	0,2554	0,6656	0,4719	0,4536	0,5205	0,5584	0,5439	0,5419	1,0000

Source: own processing

The calculation of aggregate value added norms are presented in Table 5.

Tab. 5. Calculation of aggregate value-added norms

The numbers of industry sector	The industry sector of enterprises	Aggregate value-added norm
1	The production of potash fertilizers	0,6224
2	Fuel production	0,2198
3	Manufacture of machinery and equipment	0,3985
4	Electricity and heat supply services	0,2830
5	Construction work	0,4043
6	Wholesale trade services	0,3349
7	Land transport services	0,3311
8	Services of water transport organizations	0,3394
9	Production of other goods and services	0,5100

Source: own processing

Based on the data obtained, it becomes possible to determine the multipliers of the total value-added. Hence the multiplier is (Eq. 1):

$$m = \frac{\sum_{j=1}^{M} v_j \cdot \Delta X_j}{\Delta Y_j}, \qquad (1)$$

where v_j ï unit value added per unit of product j;
ΔX_j ï the increase in gross output of the good j after increasing Y_j per unit - ΔY_j.

Consider the calculation of this multiplier on the example of the production of potash fertilizers of JSC ñUralkaliò, based on the increase in the volume of final products by one monetary unit of Eq. 1:

$$m = \frac{\sum_{j=1}^{M} v_j \cdot \Delta X_j}{\Delta Y_j} = \frac{0{,}0182 \cdot 0{,}4043 \cdot 1 + 0{,}0448 \cdot 0{,}3349 \cdot 1 + 0{,}0627 \cdot 0{,}3311 \cdot 1 + 0{,}0376 \cdot 0{,}3394}{1} + \frac{0{,}2554 \cdot 0{,}5100 \cdot 1}{1} = 0{,}88$$

The resulting multiplier indicates that an increase in sales of the final product of an enterprise producing potash fertilizers by one monetary unit provides an increase in value-added along the technological chain of production of the city of Berezniki by 0.88 monetary units. Similar multipliers were calculated for other types of economic activity. The final results of the calculations are presented in table 6.

Tab. 6. Calculation of aggregate value-added multipliers

The numbers of industry sector	The industry sector of enterprises	Aggregate value-added multiplier
1	The production of potash fertilizers	0,88
2	Fuel production	0,68
3	Manufacture of machinery and equipment	0,77
4	Electricity and heat supply services	0,78
5	Construction work	0,75
6	Wholesale trade services	0,73
7	Land transport services	0,73
8	Services of water transport organizations	0,74

Source: own processing

The resulting multiplier shows how many monetary units will increase the value-added for the considered technologically interrelated enterprises (sub-sectors or markets) with an increase in sales of final products j per unit. As can be seen from Table 6, the largest multiplier is observed in the production of potash fertilizers (1). Therefore, this type of production is the pole of economic growth in the city and the basis for the formation of a cluster that combines all the above-mentioned activities.

The determination of the capabilities and competitive advantages, which opened for business in the process of clusters organization is the next element of the methodological approach and research method. They become apparent only in the detailed calculation of economic projects related to the production and sale of cluster products. It is necessary to create a table of competitive advantage assessment, which compares these parameters for enterprises before and after joining the cluster in comparison with those competitors who are supposed to be pushed in the market. This table is formed along the technological chain of goods production from the final product to the initial intermediate resource. It should be noted that this table can be formed for products of specific enterprises that form a small cluster, and for sub-sectors or markets that are part of a large system of the territorial cluster.

The assessment of economic and competitive advantages of creating a cluster is presented in Table 7.

Tab. 7. Assessment of economic and competitive advantages of creating a cluster

Products	*Data of the leading competitor*			*Results of the functioning of the enterprises / sub-sectors / markets capable of forming a cluster*			*Change of results of functioning of the enterprises / sub-sectors / markets after cluster creation*		
	Price	*Quality*	*Sales volume*	*Price*	*Quality*	*Sales volume*	*Price*	*Quality*	*Sales volume*
Product 1 (final)	$P_{c,1}$	$S_{c,1}$	$Q_{c,1}$	$P_{l,1}$	$S_{l,1}$	$Q_{l,1}$	$\Delta P_1 = (P_{c,1} - P_{l,1})$, *if* $\Delta P_1 < 0$	$\Delta S_1 = (S_{c,1} - S_{l,1})$, *if* $\Delta S_1 > 0$	$Q_{c,1}$, *if* $\Delta S_1 > 0$ *and* $\Delta P_1 < 0$
Product 2 (intermediate)	$P_{c,2}$	$S_{c,2}$	$Q_{c,2}$	$P_{l,2}$	$S_{l,2}$	$Q_{l,2}$	$\Delta P_2 = (P_{c,2} - P_{l,2})$, *if* $\Delta P_2 < 0$	$\Delta S_1 = (S_{c,1} - S_{l,1})$, *if* $\Delta S_1 > 0$	$Q_{c,2}$, *if* $\Delta S_2 > 0$ *and* $\Delta P_2 < 0$
Product 3 (intermediate)	$P_{c,3}$	$S_{c,3}$	$Q_{c,3}$	$P_{l,3}$	$S_{l,3}$	$Q_{l,3}$	$\Delta P_3 = (P_{c,3} - P_{l,3})$, *if* $\Delta P_3 < 0$	$\Delta S_1 = (S_{c,1} - S_{l,1})$, *if* $\Delta S_1 > 0$	$Q_{c,3}$, *if* $\Delta S_3 > 0$ *and* $\Delta P_3 < 0$
é	**é**	**é**	**é**	**é**	**é**	**é**	**é**		**é**
Product n (intermediate)	$P_{c,n}$	$S_{c,n}$	$Q_{c,n}$	$P_{l,n}$	$S_{l,n}$	$Q_{l,n}$	$\Delta P_n = (P_{c,n} - P_{l,n})$, *if* $\Delta P_n < 0$	$\Delta S_1 = (S_{c,1} - S_{l,1})$, *if* $\Delta S_1 > 0$	$Q_{c,n}$, *if* $\Delta S_n > 0$ *and* $\Delta P_n < 0$

Source: own processing

Note:

$P_{c,i}$, $P_{l,i}$, $P_{k,i}$ ï prices of the *i*-th product of the leading competitor, the potential member of the cluster, respectively, before and after its organization;

$S_{c,i}$, $S_{l,i}$, $S_{k,i}$ ï an integral indicator of the quality of the *i*-th product of the leading competitor, the potential member of the cluster, respectively, before and after its organization;

$Q_{c,i}$, $Q_{l,i}$, $Q_{k,i}$ ï an integral indicator of the quality of the *i*-th product of the leading competitor, the potential member of the cluster, respectively, before and after its organization;

n - the number of types of goods planned for production within the cluster;

1.01 - the coefficient correcting value of the indicator on the small size for ensuring the enterprise of competitive advantage.

The integral quality index is proposed to be calculated by the formula characterizing the sum of dimensionless quantities calculated by the consumer characteristics of the *i*-th product (Eq. 2):

$$S_i = \sum_{j=1}^{M} \frac{s_j - s_{min}}{s_{max} - s_{\min}}, \qquad (2)$$

where s_j ï numeric value of consumer characteristic *j* for the product *i*;

s_{max} and s_{min} ï the maximum and minimum value of the consumer characteristic *j*, observed in the market.

If the value of the consumer characteristic has an inverse connection with demand, the values $1/s_j$, $1/s_{max}$ and $1/s_{min}$ are used in the calculation. If the parameter does not have a quantitative value, but only a qualitative one, then if the product has a qualitative characteristic j, its value is equal to 1 and to 0 in the opposite case. The maximum value of the quality indicator is equal to the number of consumer characteristics.

Next, we analyzed the international market of potash fertilizers. Based on the analysis, it can be noted that it is characterized by price differentiation depending on the region of sales and the length of transport routes. On this basis, for the purposes of the analysis being conducted, its geographically limited part should be emphasized on which there is a "leading" competitor whose products have the advantages in price or quality of goods. The Chinese market for potash fertilizers can be considered as such a market. On it, the Berezniki company OJSC Uralkalii (URK) confronts the OJSC Belarusian Potash Company (BPC).

Characteristics of prices, production capacity and sales volumes in the Chinese market of both companies are presented in Table 8. The data in Table 6 is given from official sources of companies OJSC Uralkalii (*ñUralkaliò leaves the world's largest mineral fertilizer markets, downloaded on 11. January 2019, available online:* https://www.vedomosti.ru/business/articles/2018/12/03/788258-uralkalii) and OJSC Belarusian Potash Company (*Belarusian Potash Company Signs New Contract With China, downloaded on 11. January 2019, available online:* https://www.vedomosti.ru/business/articles/2018/09/17/781074-belorusskaya-kaliinaya).

Tab. 8. Characteristics of the prices, production capacity and sales volume of potash fertilizers of competing companies in the Chinese market in 2017

The legal name of the company	Prices set before 2019 [USD per ton]	Sales volume, [million tons of fertilizers]
OJSC Belarusian Potash Company	290	2
OJSC Uralkalii	300	7,5

Source: own processing

To fill the data in Table 8, it is necessary to calculate the quality level indicator. Consider its calculation on the example of potash fertilizers. To this end, we choose the following main consumer characteristics of the product with the permissible level of their values indicated in brackets: mass fraction of K2O (3-63%), mass fraction of H20 (0.1-1%), mass fraction of fractions (1-4 mm), dynamic strength (80-100%), friability (5-100%). Using formula (2), we define the quality level of the products of the Belarusian Potash Company (*The products of Belaruskali, downloaded on 11. January 2019, available online:* https://kali.by/products/khloristyy-kaliy):

$$S_{1.BPC} = \sum_{j=1}^{M} \frac{s_j - s_{min}}{s_{max} - s_{min}} = \frac{60-3}{63-3} + \frac{\frac{1}{0{,}5} - \frac{1}{0{,}1}}{1 - \frac{1}{0{,}1}} + \frac{4-1}{4-1} + \frac{85-80}{100-80} + \frac{100-5}{100-5} = \mathbf{4{,}09}$$

A similar calculation of the quality indicator for the characteristics of potash fertilizers of OJSC Uralkali (*Product Catalog ñUralkaliò, downloaded on 11. January 2019, available online: http://pda.uralkali.com /upload/content/products/Products_catalogue_ru.pdf*) indicates that it is at about the same level:

$$S_{1.URK} = \sum_{j=1}^{M} \frac{s_j - s_{min}}{s_{max} - s_{min}} = \frac{60-3}{63-3} + \frac{1 - \frac{1}{0{,}1}}{1 - \frac{1}{0{,}1}} + \frac{4-1}{4-1} + \frac{80-80}{100-80} + \frac{100-5}{100-5} = \mathbf{4}$$

The next intermediate product is diesel fuel. In Belorussia, one litre of this fuel cost 0.78 USD per litre in 2017 (How much does fuel cost in Belarus? *downloaded on 11. January 2019, available online:* https://www.blr.cc/benzin), and in Russia, it was equal to 0.67 USD. The quality of diesel fuel can be assessed by its characteristics: viscosity, density, surface tension, fractional composition and pressure of saturated fuel vapours. To simplify the calculation, in view of the identity of the production technology, we take its value at level 5 by the number of consumer characteristics. It can be noted that competitors have no advantages in this technological chain of production, and there is no need for any coordination actions of fuel producers with the exception of logistics.

The next intermediate product used in the technological chain of potash production is engineering products. Since it is diverse in purpose, consumer qualities and cost, it should focus on the equipment, the introduction of which in the potash industry will provide it with a competitive advantage. In accordance with the annual report of Uralkali, 8% of the cost of potash fertilizers is the cost of repairing mining tunnelling machines and other technological equipment, which is USD 41.92 million (Integrated report of "Uralkali", *downloaded on 11. January 2019, available online: https://www.uralkali.com/upload/iblock/0dc/uralkali_ar2017_rus.pdf).* In this regard, at JSC Berezniki Mechanical Plant (hereinafter BMZ), within the cluster, repair works of equipment of JSC Uralkali can be arranged at a lower price due to the proximity of the location of the repair production and its raw material base. The required capital investments in its organization are approximately equal to 61 million

USD. However, according to the accounting statements of BMZ, the net profit will be enough to invest only 8 million USD. Hence the need to use the funds of cluster enterprises arises that can benefit from such innovation.

Thus, the selected production and numerical parameters should be recorded in Table 9:

Tab. 9. Assessing the economic and competitive advantages of creating a cluster

Products	Data of the leading competitor			Results of the functioning of enterprises / sub-sectors / markets capable of forming a cluster			Change of results of functioning of enterprises / sub-sectors / markets after the creation of a cluster		
	Price	Quality	Sales volume	Price	Quality	Sales volume	Price	Quality	Sales volume
Potash fertilizers	$290 /ton	4,09	2 million tons	$300 /ton	4	7,5 million tons	$289,9 /ton	4	2 million tons
Fuel	$0,78 per litre	5	36212, 6 thousand litres	$0,67 per litre	5	163543,8 thousand litres	$0,67 per litre	5	43611,68 thousand litres
Repair of mining equipment	-	-	$21,72, million	-	-	4$1,92, million	-	-	$21,72, million

Source: own processing

It should be noted that since energy supply, heat supply, and transportation services belong to natural monopolistic activities, and there is no competition for them in the city of Berezniki, it does not make sense to analyze the possibility of increasing their competitiveness.

Construction and wholesale services in the city of Berezniki are represented by numerous firms competing with each other. Therefore, the coordination of their activities does not make sense, since the "narrow" places for the cluster are eliminated in the process of competition.

As can be seen from Table 8, in order to provide the necessary competitive advantage in the sale of final goods, it is necessary to reduce the price of potash fertilizers by 10.1 USD ((300-290)*1.01). This will push the competitor out of the market and increase sales by 2 million tons. To this end, analyzing the possibility of reducing costs along the technological chain of production, you can see that reducing repair costs by at least 20.2 million USD (10.1 Ã2 million tons) will allow acquiring the desired competitive advantage.

Discussion

Using the author's methodology for calculating the economic efficiency of the newly created cluster, high positive values were obtained from the creation of a cluster around an enterprise for the extraction of potassium salts and the production of potash fertilizers. For the final confirmation of this possibility, it is required to calculate the indicators

The forecast horizon of indicators was 5 years, based on the depreciation period of the equipment in which it is proposed to invest.

Additional profits of enterprises from the organization of the cluster is determined as follows:

1) for JSC ñUralkaliò:

$$Pr_{URK,1} = \left(Pr1_{i,i} \cdot Q_{c,i} - SN_{pr,i}\right) \cdot (1 - N_{in}) = (289{,}9 \cdot 0{,}3952 \cdot 2 - 0) \cdot (1 - 0{,}2) = \$183{,}31\ mln$$

where 289,9 ï price per ton of potash fertilizer with a competitive advantage, USD / ton;
0.3952 - coefficient characterizing the profitability of sales;
2 - the volume of additional sales of potash fertilizers as a result of displacing a competitor from the Chinese market;
0.2 is the coefficient characterizing the tax rate on profits in the Russian Federation.

2) for diesel manufacturers:

$$Pr_{FOT,2} = \left(Pr_{FOT,2} \cdot Q_{c,2} - SN_{pr,FOT}\right) \cdot (1 - N_{in}) = \left(v_j \cdot \Delta X_j - SN_{pr,FOT}\right) \cdot (1 - N_{in}) = \left(v_j \cdot b_{i,j} \cdot \Delta Y_j - SN_{pr,FOOT}\right) \cdot (1 - N_{in}) = (0{,}2198 \cdot 0{,}0689 \cdot 289{,}9 \cdot 2 - 0) \cdot (1 - 0{,}2) = \$7{,}02\ mln$$

where 0.2198 ï the coefficient characterizing the rate of value-added in the price of diesel fuel,
0.0689 - the ratio of the full cost of the use of diesel fuel in the production of one ton of potash.

It should be noted that the increase in profits from the additional sales of diesel fuel is formed by increasing the amount of fuel consumed as a result of the growth in the output of final products. Hence, the sales volume of diesel fuel, indicated in table 6, was calculated according to the technological production chain as follows:

$$Q_{c.2} = Q_{c.1} \cdot \frac{Q_{l.2}}{Q_{l.1}} = 2 \cdot \frac{163543{,}8}{7{,}5} = 43611{,}68\ tous.l.$$

3) for the JSC "Berezniki Mechanical Plant" profit will be:

As can be seen in Table 7, the annual profit is taken into account at the same level, based on the preservation of competitive advantage. Depreciation charges are formed only at the enterprise BMZ, as it is the only enterprise that makes investments. In the process of discounting cash flows, the discount rate (Yon) was taken into account, based on the bank interest rate on the US dollar at 2.5%. The net present value was determined by the traditional formula:

$$NPV = \sum_{t=1}^{T} \frac{CF_t}{(1+i)^{t-1}}, \tag{3}$$

Where CF_t is the cash flow of the enterprise l for the year t, mln. USD,
i - the interest rate on the US dollar,
T - forecast horizon, years.

The results of the simulation of cash flow from the creation of a mining cluster in the city of Berezniki presented in Table 10.

Tab.10. Simulation of cash flows from the creation of a mining cluster in the city of Berezniki [million USD]

Indicator	Forecast horizon, years				
	1	2	3	4	5
Additional capital investment	61	0	0	0	0
- investments of JSC Uralkali	0	0	0	0	0
- investments of diesel fuel manufacturers	0	0	0	0	0
- investments of JSC "Berezniki Mechanical Plant"	61	0	0	0	0
Additional profit	195,715	195,715	195,715	195,715	195,715
- profit of JSC Uralkali	183,31	183,31	183,31	183,31	183,31
- profit of diesel fuel manufacturers	7,02	7,02	7,02	7,02	7,02
- profit of JSC "Berezniki Mechanical Plant"	5,385	5,385	5,385	5,385	5,385
Additional depreciation	12,2	12,2	12,2	12,2	12,2
- increase in depreciation of JSC Uralkali	0	0	0	0	0
- increase in depreciation of diesel fuel manufacturers	0	0	0	0	0
- increase in depreciation of JSC "Berezniki Mechanical Plant"	12,2	12,2	12,2	12,2	12,2
Cash flows (ч F_t):	146,915	207,915	207,915	207,915	207,915
- JSC Uralkali	183,31	183,31	183,31	183,31	183,31
- diesel fuel manufacturers	7,02	7,02	7,02	7,02	7,02
- JSC "Berezniki Mechanical Plant"	-43,415	17,585	17,585	17,585	17,585
Discount coefficient $(1/(1+i)^{t-1})$	1	0,9756	0,9518	0,9286	0,9060
Net discounted cash flow	146,915	202,84	197,896	193,07	188,361
- JSC Uralkali	183,31	178,839	174,477	170,222	166,07
- diesel fuel manufacturers	7,02	6,848	6,681	6,518	6,359
- JSC "Berezniki Mechanical Plant"	-43,415	17,156	16,737	16,329	15,931
Cumulative net present value (NPV)	146,915	349,759	547,655	740,725	929,086
The rate of compensation of negative cash flow	22,18				
Compensation of losses to companies with negative cash flow	42,220				
- JSC Uralkali	40,663				
- diesel fuel manufacturers	1,557				
- JSC "Berezniki Mechanical Plant"					

Source: own processing

Analyzing Table 10, we can conclude that since NPV> 0, then cluster organization is beneficial for its participants. However, in the first year, enterprise BMZ has significant investment costs. As a result, it can refuse them. To prevent this from happening, formula (4) was used to calculate the rate of compensation for its losses - 22.18.

$$m = \frac{\sum_{j=1}^{n} |F_{l,i}|}{\sum_{j=1}^{n} Pr_{l,i}}, \tag{4}$$

On this basis, in the same table, a part of the profit of each enterprise was determined, which it will receive as a result of the work of the cluster and which it will need to invest in the composition of the JSC Berezniki Mechanical Plant. These investments will pay off in the first year. Their return by JSC Berezniki

Mechanical Plant can be stipulated for a five-year period during which this enterprise will be able to painlessly compensate investments from the accumulated depreciation fund.

Conclusion

From the research results, we can draw the following conclusions.

Cluster organization of activity has a positive impact on competitive advantages and sustainable development of all enterprises of the city and municipality.

Our studies were limited to one mining area (Berezniki industrial centre), and the results were obtained for a sample of enterprises in the city of Berezniki and the Berezniki municipal district. Whether this model and the results are true for other mining areas is something that should be considered in future studies.

Another direction of future research is to identify the relationship between the industrial cluster and innovation. To carry out this study will require a more detailed analysis of data on specific industrial networks, on the dynamics of intercluster connections within and between regions.

Also, as further research, it is planned to expand the proposed industrial cluster model to the technopark model, complementing it with scientific and educational organizations, innovation infrastructure organizations, and technology park support infrastructure.

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