BIO Web of Conferences **116**, 06013 (2024) https://doi.org/10.1051/bioconf/202411606013
EBWFF 2024

Ecological consequences of industrial regions sectoral specialization

Natalia Logacheva[1], *Dmitri* Pletnev[1], and *Artyom* Uzhegov[1*]

[1] Institute of Economics, Ural Branch of the Russian Academy of Sciences, 620014, Moskovskaya str., 29, Ekaterinburg, Russia

Abstract. The purpose of the study is to determine the degree of influence of sectoral specialization of industrial regions on the environmental situation, to understand whether there is a relationship between the level of technological specialization of the region and the environmental situation. In the study, the criterion for classifying regions as industrial is the share of manufacturing industries in the sectoral structure of gross value added of more than 30% during 2017-2020. The article uses the following research methods: statistical analysis, correlation analysis, comparison, contrast, coefficient calculation. In the study, the authors: a) grouped the types of economic activities of industrial regions by the level of technological development; b) analyzed the volume of industry in the context of economic activities for 2018, 2022; c) analyzed the degree of industry specialization; d) the share of captured and neutralized air pollutants in the total amount of waste pollutants from stationary sources in industrialized regions was analyzed; e) presented a correlation table, which reflects the relationship between the level of specialization of the main industry and the share of captured and neutralized air pollutants in the total amount of waste pollutants from the stationary The authors made conclusions that the regions, whose production specialization is more high-tech, have a better environmental situation. Thus, the development of high-tech industries can stimulate regions to diversify production and switch to more environmentally friendly production methods. This can lead to a reduction in negative environmental impact and an improvement in the quality of life. In the case of industrialized regions with a predominant share of metallurgy, it is important to undertake measures to update production processes and introduce environmental innovations.

1 Introduction

At present, the issue of sustainable regional development attracts much attention of researchers around the world. Many authors draw attention to the importance of studying this issue [1; 2]. Of particular interest are industrial regions, which have become the object of attention due to their industrial specialization. The analysis of the relationship between industrial specialization, technological level and ecology allows us to identify potential threats to the environment, as well as to identify areas for improving the environmental

* Corresponding author: uzhegov.ao@uiec.ru

sustainability of the region [3].
In 1970-1980, scientists paid attention to the impact of environmental factors on the quality of life of people, when the violation of ecological balance became obvious and the problem of analyzing the relationship between the quality of life and the state of the environment arose [4]. Until then, it was believed that economic growth had no limits and was not related to population size and the use of natural resources. Only at the end of the last century the connection between ecology, economy and quality of life became clearly visible. The growth of production was confronted with the limitations of natural resources, which were previously considered inexhaustible. The negative consequences of economic growth, such as environmental pollution and deterioration of public health, also became clearly visible. Thus, the study of the impact of industrial specialization of industrial regions and the level of its technological sophistication on the environmental situation is of great importance for the development of sustainable development strategies and the creation of more environmentally sustainable production models [5; 6].

2 Literature Review

The study of industrial regions of the Russian Federation is necessary to understand the economic processes taking place in the regions and to develop effective strategies for their development. As part of the industrial system, each region has specialization, which is the concentration on its territory of specific types of industries that satisfy with their products not only their own needs, but also the needs of other regions of the country.

A number of studies have touched upon the issues of specialization of territories in certain types of industry.

N. S. Kozyr compares the economic specializations of the regions of the Russian Federation with the types of activities described in the «All-Russian Classifier of Economic Activities 2021». The author compared the obtained data with the statistics of gross value added of the sectoral structure of Russia. The paper also analyzed the representation of high-tech and knowledge-intensive industries in the prospective economic specializations of regions [7].

M. Brühlhart, examines the change in the geographical concentration of manufacturing industries in Europe. The author analyzes data for the period from 1972 to 1995 and concludes that there is an increase in the concentration of production in certain regions, while other regions are losing their importance. The study shows that high concentration of production has its advantages, such as the availability of skilled labor, infrastructure, and markets. However, the author notes that there are also risks associated with market monopolization and lack of competition. Brühlhart also points out that changes in geographical concentration of production can be linked to changes in economic policy and technological development. For example, the author points to a significant increase in the concentration of production in Germany during the 1980s, which was associated with reforms in the economy and the development of new technologies [8].

The study analyzed methodologies for assessing environmental and economic factors of sustainable development. This allowed the authors to develop an algorithm that takes into account the peculiarities of the regional context and the specifics of the tasks they face. This approach allows to obtain more accurate and relevant data, as well as to solve the problems of sustainable development in a particular region more effectively [9].

E. V. Ryumina in her study analyzes the relationship between environmental indicators and the quality of life of the population in different regions of Russia. The work applied a methodology for assessing the environmental characterization of the quality of life of the population, which includes the assessment of such indicators as environmental safety, consumption of natural resources, ecological state of the environment, etc. Various indicators, factors and variables were used in the work, including the level of environmental pollution, the level of morbidity of the population, environmental protection costs, etc. The merit of this study is its relevance and significance in understanding the relationship between environmental indicators and the quality of life of the population. In addition, the use of various methods of statistical analysis allowed us to obtain more accurate and objective results. The drawbacks of the study include the limited sample size of statistical indicators. In addition, the methodology of environmental characterization of the population's quality of life can be subject to subjective perception and assessment [10].

V. S. Tikunov and S. K. Belousov emphasize their attention on the study of anthropogenic factor impact on the natural environment in different regions of Russia. The work used methods of integral assessment and mapping, including analysis of geographic information system data, mathematical modeling and statistical data analysis. The methodology of anthropogenic impact assessment on the natural environment was also applied, which includes assessment of such indicators as air, water and soil pollution, noise level, landscape change, etc. Various indicators, factors and variables were used in the work, including emissions into the atmosphere from stationary sources and motor transport, discharge of untreated and insufficiently treated wastewater, production and consumption wastes that have not been recycled or neutralized, etc. The merit of this study, is its relevance and significance for understanding the impact of anthropogenic factor on the natural environment in different regions of Russia. In addition, the use of various methods of integral assessment and mapping allowed to obtain more accurate and objective results [11].

M. Tengiz in his study analyzes the energy security of the territory of Georgia in the context of sustainable development. The work used the methods of system analysis and economic and mathematical modeling, as well as the methodology of energy security assessment. The study indicators were energy indicators such as energy consumption, production and import of energy resources, energy consumption structure, as well as environmental security indicators such as emissions of harmful substances and level of environmental pollution. Factors and variables used were data on the country's economic development, level of investment in the energy sector, availability and development of renewable energy sources and energy efficiency measures. The advantage of this study is the use of a systematic approach and economic and mathematical modeling, which allows taking into account many factors and variables when assessing the energy security of the territory. The author's model can be adapted to other countries and territorial structures. The disadvantages of the work include the limited number of used indicators and factors, which may not allow to fully cover all aspects of energy security of the territory [12].

A. S. Lee considers the algorithm for assessing the level of sustainable development of the region. The work used the methods of economic analysis, mathematical statistics and modeling. The methodology in the study is to determine the index of sustainable development of the region based on the analysis of economic, social and environmental indicators. The advantage of this study is its comprehensive approach to assessing the sustainable development of the region, as well as the use of various methods to achieve this goal. The disadvantages include the lack of a sample of regions for approbation of the study [13].

J. Benedek, K. Temerdek-Ivan, I. Török, A. Temerdek, and I. Holobaca focus their research on assessing local and regional progress in achieving the Sustainable Development Goals (SDGs) in Romania. Holobaca focuses on assessing local and regional progress in achieving the Sustainable Development Goals (SDGs) in Romania. The paper used an indicator approach, which allows measuring and analyzing progress towards the SDGs based on specific indicators. Various indicators such as poverty, health, education, economic growth, energy efficiency and others were used to assess the progress towards the SDGs. In addition, data on the socio-economic development of Romania's regions, as well as on the measures taken to achieve the SDGs were used in the paper. The advantage of this study is the use of an indicator approach, which allows measuring and analyzing the progress in achieving the SDGs based on specific indicators. Also, the use of data on the socio-economic development of the Romanian regions allows taking into account local characteristics and needs when assessing progress towards the SDGs. The shortcomings of the work include the limited number of indicators and factors used, which may not allow to fully cover all aspects of progress towards the SDGs [14].

D. V. Bobin's research is devoted to the assessment of energy efficiency of socio-ecological-economic systems of regions. The author used the method of multicriteria optimization, which allows us to assess the efficiency of resource use and improvement of the environmental situation in the regions. The work used the indicators of efficiency of economic, social and environmental subsystems. Thus, the set of initial data represents information on eighty-four observations (subjects of the Russian Federation) on twenty attributes grouped by three factors. The advantage of this study is the use of multi-criteria optimization method, which allows taking into account several indicators when assessing the effectiveness of the system. Also, the author used a broad base of indicators and factors, which allows to obtain a more accurate assessment. The peculiarity of the generated data is the presence of omissions in observations for one dimension or more, i.e. it is not possible to establish the values of some indicators for a number of regions [15].

The conducted literature research allowed us to identify the authors' approaches to the definition of environmental and economic factors affecting the development of regions. At the same time, this study has emphasized the need for a deeper analysis of regional specialization and determination of the level of their technological sophistication in order to understand how these factors affect the environmental situation in the regions. Thus, it becomes relevant to study the issues of determining the specialization of regions and assessing the level of their technological sophistication, as well as to identify the impact of this level on the environmental situation in these regions. Further research in this area may help to develop more effective sustainable development strategies that take into account the relationship between industrial specialization and environmental aspects of regional development.

3 Data and methods

This study represents the development of methodological approaches to the study of industrial regions of the Russian Federation with a focus on their sectoral specialization and environmental situation. Taking into account that industrial regions often face problems of unfavorable ecology, special attention is paid to the analysis of the impact of production processes on the environment. The purpose of the study is to determine the degree of influence of industrial specialization of industrial regions on the environmental situation, to understand whether there is a relationship between the level of technological specialization of the region and the environmental situation. The article uses the following research methods: statistical analysis, correlation analysis, comparison, contrast, coefficient calculation. In the study, the criterion for classifying regions as industrialized is the share of manufacturing industries in the sectoral structure of gross value added of more than 30% during 2017-2020. The research algorithm included the following stages:

1)Types of economic activities (FEA) were presented in accordance with the structure of the volume of shipped products (works, services) by the type of economic activity «Manufacturing industries». Grouping of FEAs by the level of technological development was carried out

2)The share of the volume of shipped products (works, services) by type of economic activity «Manufacturing industries» in the context of FEA for 2018, 2022 was analyzed. The results of this stage made it possible to determine the dynamics of changes in industry in various sectors of the economy.

3)The degree of industry specialization was analyzed, which are calculated as coefficients of industry specialization.

4)The share of captured and neutralized air pollutants in the total amount of waste pollutants from stationary sources (conventional designation for this indicator is CO_2) in industrialized regions was analyzed.

5)Based on the calculated coefficients of specialization by FEA, as well as taking into account the environmental component, a correlation table was presented, which reflects the relationship between the level of specialization of the main industry and the share of captured and neutralized air pollutants in the total amount of waste pollutants from stationary sources.

4 Results

Based on the presented research algorithm, the types of economic activities (FEA) are presented in accordance with the structure of the volume of shipped products (works, services) by type of economic activity «Manufacturing industries» and the conventional designations are introduced:

– production of coke and petroleum products in % of the type of economic activity «manufacturing industries» (X1);

– production of other non-metallic mineral products in % of the type of economic activity «manufacturing industries» (X2);

– metallurgical production as % of type of economic activity «manufacturing industries» (X3);

– repair and installation of machinery and equipment in % of economic activity «manufacturing industries» (X4).

– production of chemicals and chemical products, production of medicines and materials used for medical purposes in % of economic activity «manufacturing industries» (X5);

– manufacture of machinery and equipment as a % of economic activity «manufacturing industries» (X6).

– manufacture of computers, electronic and optical products; manufacture of electrical equipment in % of economic activity «manufacturing industries» (X7).

Further, types of economic activities were grouped according to the level of technological development, into three groups in accordance with the list of industries of a high technological level, medium high technological level and knowledge-intensive industries of Federal State Statistics Service (Rosstat): a) Medium-tech low level – X1-X4; b) Medium-tech high-level – X5 and X6; c) High-tech – X7.

Table 1 shows the dynamics of the share of the volume of shipped products (works, services) by type of economic activity «manufacturing industries» by FEA for 2018, 2022.

Table 1. Dynamics of the share of the volume of shipped products (works, services) by type of economic activity «manufacturing industries» by FEA for 2018, 2022, in percent

Regions	Years	X1	X2	X3	X4	X5	X6	X7	Sum of X1-X7 of the total number of FEAs
Russian Federation	2018	**25,8**	3,6	19,2	2,4	8,6	13,4	5,3	78,3
	2022	**23,7**	3,9	21,7	2,1	10,6	9,6	5,1	76,7
	Change 2022 to 2018	-2,1	0,3	2,5	-0,3	2	-3,8	-0,2	-1,6
Tula region	2018	2	4,1	**40,7**	0,8	22,1	2	4,1	75,8
	2022	1,6	4,2	**37,2**	0,6	20,2	8,3	3,7	75,8

	Change 2022 to 2018	-0,4	0,1	-3,5	-0,2	-1,9	6,3	-0,4	0
Vologda region	2018	1,2	1,7	**60,6**	0,9	19,4	1,7	0,3	85,8
	2022	2,1	2,1	**53,1**	0,9	27,7	1,4	0,8	88,1
	Change 2022 to 2018	0,9	0,4	-7,5	0	8,3	-0,3	0,5	2,3
Kaluga region	2018	8	4,4	11	0,6	5,1	**39,1**	12,8	81
	2022	9,4	6,8	14,6	0,4	8,6	**15,9**	10,6	66,3
	Change 2022 to 2018	1,4	2,4	3,6	-0,2	3,5	-23,2	-2,2	-14,7
Krasnoyarsk region	2018	2,8	1,6	**75,3**	4,1	3,6	3,2	1	91,6
	2022	3,1	2,3	**74,2**	4,3	3,2	2,1	1,3	90,5
	Change 2022 to 2018	0,3	0,7	-1,1	0,2	-0,4	-1,1	0,3	-1,1
Lipetsk region	2018	1,8	1,5	**68,4**	0,5	1,2	2	3,6	79
	2022	1,3	1,5	**62,2**	0,9	3	2,5	1,8	73,2
	Change 2022 to 2018	-0,5	0	-6,2	0,4	1,8	0,5	-1,8	-5,8
Novgorod region	2018	0,8	8,3	2,7	3,7	**35,5**	4,2	4,1	59,3
	2022	1,1	5,4	3,9	1,7	**51,8**	2,9	4,1	70,9
	Change 2022 to 2018	0,3	-2,9	1,2	-2	16,3	-1,3	0	11,6
Omsk region	2018	**76,3**	0,6	2,2	1,1	6,2	2,3	2,1	90,8
	2022	**28,6**	2,2	7,9	3	16,8	6,5	6,7	71,7
	Change 2022 to 2018	-47,7	1,6	5,7	1,9	10,6	4,2	4,6	-19,1
Vladimir region	2018	6,1	6,9	**13,6**	0,7	9,6	7,1	12	56
	2022	6,9	6,8	11,1	0,6	9,8	6,9	**11,2**	53,3
	Change 2022 to 2018	0,8	-0,1	-2,5	-0,1	0,2	-0,2	-0,8	-2,7
Chelyabinsk region	2018	3	6,7	**62,1**	2,2	3,3	9,2	3	89,5
	2022	3,2	6,8	**61,5**	2,2	3	10,4	2,6	89,7
	Change 2022 to 2018	0,2	0,1	-0,6	0	-0,3	1,2	-0,4	0,2
Sverdlovsk region	2018	2	4,3	**62,7**	2,1	4,1	12,4	4	91,6
	2022	2,1	4,9	**61,6**	2,6	4,8	10,4	4,3	90,7
	Change 2022 to 2018	0,1	0,6	-1,1	0,5	0,7	-2	0,3	-0,9

Source: compiled by the authors

The analysis of the data in Table 1 allowed us to draw a number of conclusions:

In general, since 2018, the share of the volume of shipped products of FEA X1-X7 in the economy of the Russian Federation decreased by 1.6%, to a greater extent this is due to the reduction of the share of industry in FEA X6 – production of machinery and equipment and X1 – production of coke and petroleum products. The largest growth is demonstrated by FEA X3 – metallurgical production (2.5%). At the same time, FEA X1 has the largest share in the structure of the RF industry – 23.7% in 2022. The largest share in the industrial structure of the Tula region is occupied by FEA X3 – metallurgical production (37.2% in 2022). The largest increase was recorded in FEA X6 – production of machinery and equipment and amounted to 6.3% in 2022. In general, the share of the volume of shipped products of FEA X1-X7 in the economy of the Tula region in 2022 retained its 2018 values. In the Vologda region, the largest share in the structure of industry is recorded in FEA X3 – metallurgical production and amounts to 53.1% in 2022. In general, since 2018, the share of the volume of shipped products of FEA X1-X7 in the economy of the Vologda region increased by 2.3% The Kaluga region is characterized by a high share in the structure of FEA X6 industry –

mechanical engineering (15.9%). In general, the share of the volume of shipped products of FEA X1-X7 in the regional economy in 2022 shows a decrease by 14.7%. In Krasnoyarsk region, the largest share in the industrial structure is recorded in FEA X3 – metallurgical production and amounts to 74.2% in 2022. Overall, since 2018, the share of the volume of shipped products of FEAs X1-X7 in the Krasnoyarsk region economy has decreased by 1.1%. The largest share in the industrial structure of the Lipetsk region is occupied by FEA X3 – metallurgical production (62.2% in 2022). In general, the share of the volume of shipped products of FEA X1-X7 in the region's economy in 2022 shows a decrease by 5.8%. The Novgorod region is characterized by a high share in the industry structure of FEA X5 – production of chemicals and chemical products (51.8%). Overall, the share of the volume of shipped products of FEAs X1-X7 in the regional economy in 2022 shows an increase of 11.6%. In the Omsk region the largest share in the structure of industry is recorded in FEA X1 – production of coke and petroleum products and amounts to 28.6% in 2022. In general, since 2018, the share of the volume of shipped products of FEA X1-X7 in the economy of the Omsk region decreased by 19.1%. In the Vladimir region, the largest share in the structure of industry in 2018 was FEA X3 – metallurgical production (13.6%), in 2022 FEA X7 – production of computers, electronic and optical products (11.2%). It should be noted that this is the only region that has a change in dominant industry in 2022. In general, the share of the volume of shipped products of FEA X1-X7 in the economy of Vladimir region in 2022 shows a decrease of 2.7%. The largest share in the industrial structure of the Chelyabinsk region is occupied by FEA X3 – metallurgical production (61.5% in 2022). In general, the share of the volume of shipped products of FEA X1-X7 in the economy of the Chelyabinsk region in 2022 shows an increase of 0.2%. In the Sverdlovsk region, the largest share in the structure of industry is recorded in FEA X3 – metallurgical production and amounts to 61.6% in 2022. In general, since 2018, the share of the volume of shipped products of FEA X1-X7 in the regional economy decreased by 0.9%.

Thus, the data of the table allowed us to identify five groups of regions by the largest share of the volume of shipped products for 2022: a) with the priority industry «metallurgy» – 6 regions (Krasnoyarsk, Tula, Vologda, Lipetsk, Chelyabinsk and Sverdlovsk regions); b) with the priority industry «mechanical engineering» – 1 region (Kaluga region); c) with a priority industry of chemical production – 1 region (Novgorod region); d) with a priority industry of petrochemical industry – 1 region (Omsk region); e) with a priority industry of computers, electronic and optical products – 1 region (Vladimir region). According to the level of technological development of the presented industries, it should be noted that the largest share of high-tech industries is observed in the Vladimir region (11.2), and the smallest in the Vologda region (0.8). High-level medium-technology industries are concentrated in the Kaluga and Novgorod regions. Low-level medium-technology industries prevail in seven out of ten regions, among which Krasnoyarsk, Tula, Vologda, Lipetsk, Chelyabinsk and Sverdlovsk regions with metallurgical production, as well as Omsk region with the production of coke and petroleum products, stand out. Thus, to a greater extent the sectoral specialization of industrial regions is represented by metallurgical industry. It is these industries that belong to the medium-technology low-level manufacturing industry.

To determine how much the region is specialized in a particular industry compared to the average value in the Russian Federation, the degree of industry specialization is analyzed, which is calculated as a coefficient of industry specialization [16].

The coefficient of specialization of the region in a particular industry is calculated by the formula:

$$KSir = \frac{\frac{Vr}{Vc}}{\frac{GRP}{GDP}} \quad (1),$$

KSir (Specialization coefficient) - specialization coefficient of the i-th industry in the region r;
Vr (Volume of production in the region) - volume of production of a particular industry in the region;
Vc (Volume of production in the country) - volume of production of a particular industry in the country;
GRP - volume of gross output in the region r;
GDP - volume of gross output in the country.

Thus, the specialization coefficient assesses the degree of specialization of the region in the industry sector relative to the average for the Russian Federation.

To determine the level of specialization of the manufacturing sector in the structure of industrial production of industrial regions, the corresponding specialization coefficients were calculated (Table 2).

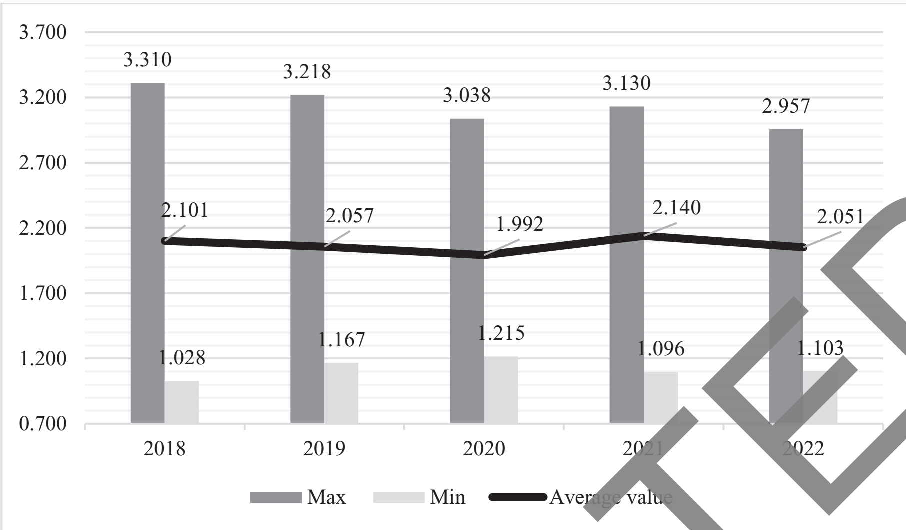
Table 2. Specialization coefficient of manufacturing industries in the industrial structure of industrial regions for 2018-2022.

№	Regions	2018	2019	2020	2021	2022
1	Tula region	2,133	2,194	2,301	2,402	2,534
2	Vologda region	2,276	2,232	2,231	2,363	2,496
3	Kaluga region	3,310	3,218	3,038	3,130	2,660
4	Krasnoyarsk region	1,028	1,167	1,215	1,096	1,103
5	Lipetsk region	2,533	2,401	2,312	2,697	2,957
6	Novgorod region	1,570	1,483	1,471	1,852	2,007
7	Omsk region	2,642	2,503	2,147	2,243	1,127
8	Vladimir region	1,889	1,841	1,846	1,979	1,941
9	Chelyabinsk region	1,983	1,918	1,743	2,024	1,989
10	Sverdlovsk region	1,643	1,612	1,614	1,610	1,699

Source: calculated by the authors on the basis of the data Regions of Russia. Main characteristics of the subjects of the Russian Federation / Federal State Statistics Service, 2023. URL: https://rosstat.gov.ru/storage/mediabank/Region_Pokaz_2023.pdf (date of reference 08.04.2024).

Analyzing the data presented in Table 2. it is noted that the highest value of the specialization coefficient in 2022 is observed in the Lipetsk region (2.957), and the lowest value in Krasnoyarsk region (1.103). All industrial regions demonstrate a high specialization coefficient in manufacturing industries.

The graphical interpretation of the level of specialization of the manufacturing industry (in terms of maximum, average and minimum values) is presented in Figure 1.



Source: compiled by the authors

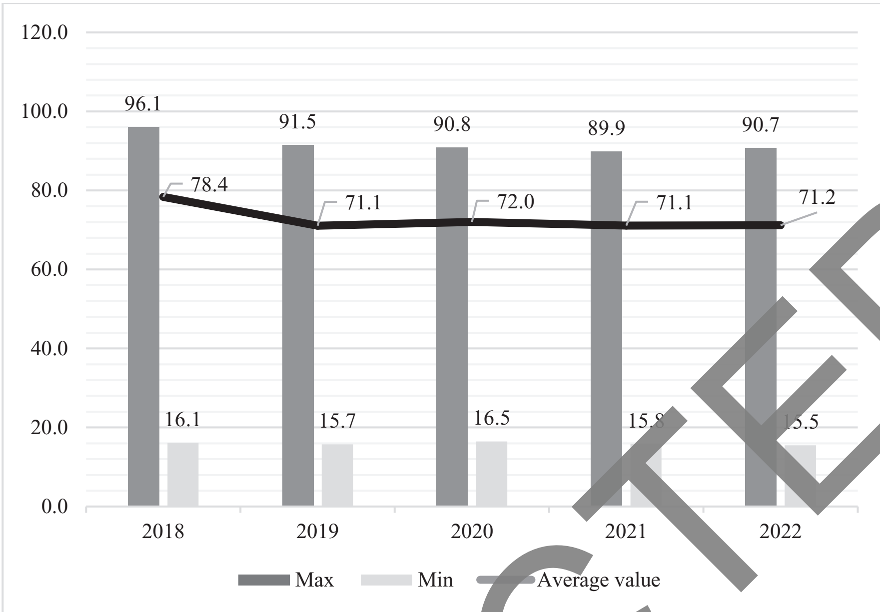
Fig. 1. Dynamics of the specialization ratio for industrialized regions (corridor), 2018-2022.

The maximum value of the specialization coefficient for the period from 2018 to 2021 is recorded in the Kaluga region, in 2022 the highest value of the indicator is recorded in the Lipetsk region. The minimum value for the entire study period was recorded in Krasnoyarsk region. The average value is calculated as the arithmetic mean of this group of regions.

The analysis of the dynamics of the specialization coefficient of manufacturing industries shows the following: in 2022 compared to 2018, a decrease in the specialization coefficient was recorded in two regions: in the Kaluga and Omsk regions (by 0.649 and 1.515, respectively). The remaining industrial regions are characterized by an increase in the specialization coefficient in 2022 compared to 2018. The largest increase in the specialization coefficient is recorded in the Novgorod region and amounts to 0.438. The following points were noted during the analysis: in the period from 2018 to 2022, the highest specialization coefficient was recorded in the Kaluga region in 2018 and amounted to 3.310, in the Lipetsk region in 2022 with a value of 2.957, in the Omsk region in 2018 with a value of 2.642, in the Tula region in 2022. with the value of 2.534, in the Vologda region in 2022 with the value of 2.496, in the Chelyabinsk region in 2021 with the value of 2.024, in the Novgorod region in 2022 with the value of 2.007, in the Vladimir region in 2021 with the value of 1.979, in the Sverdlovsk region in 2022 with the value of 1.699, in the Krasnoyarsk region in 2020 with the value of 1.215.

Summarizing the above, it is noted that in comparison with other regions of Russia, all industrialized regions have high specialization coefficients in the manufacturing industry.

Figure 2 presents a graphical interpretation of the share of captured and neutralized air pollutants in the total amount of waste pollutants from stationary sources in industrialized regions (in terms of maximum, average and minimum values)



Source: compiled by the authors

Fig. 2. Dynamics of the share of captured and neutralized air pollutants in the total amount of waste pollutants from stationary sources for industrialized regions, in percent (corridor), 2018-2022.

The maximum value of CO_2 for the period from 2018 to 2022 was recorded in the Omsk region. The minimum value for the entire study period was recorded in the Vladimir region. The average value is calculated as the arithmetic mean of this group of regions.

The analysis of CO_2 dynamics demonstrates the following: in 2022 compared to 2018, a decrease in this indicator was recorded in the following regions: in the Vladimir region by 0.6 percentage points (p.p.), in the Kaluga region by 24 p.p., in the Lipetsk region by 7 p.p., in the Vologda region by 14 p.p., in the Novgorod region by 25.2 p.p., in the Krasnoyarsk region by 2.7 p.p., in the Omsk region by 2.5 p.p. The remaining industrialized regions are characterized by an increase in the value of CO_2, in 2022 compared to 2018. The largest increase in this indicator is recorded in the Chelyabinsk region and amounts to 2.3 p.p.

On the basis of the calculated specialization coefficients by FEA, as well as taking into account the environmental component, a correlation table was presented, which reflects the relationship between the level of specialization of the main branch of industry and the share of captured and neutralized air pollutants in the total amount of waste pollutants from stationary sources (Table 3).

Table 3. Interrelation of sectoral specialization of industrial regions and ecology*

Regions and their sectoral specialization	2018		2019		2020		2021		2022		Correlation coefficient
	KSir	CO_2	KSir	CO_2	KSir	CO_2	KSir	CO_2	KSir	CO_2	
Tula region / X3	3,6	78,5	3,8	87,2	4,8	83,8	4,4	77,6	4,3	79,0	-0,0199
Vologda region / X3	5,8	85,4	5,5	62,8	5,7	68,7	6,7	67,6	6,1	71,4	-0,0247
Kaluga region / X6	9,2	87,9	9,3	62,1	8,4	62,5	7,9	60,5	4,4	63,9	0,3132
Krasnoyarsk region / X3	3,2	73,4	3,9	68,3	4,3	69,3	3,7	65,9	3,8	70,7	-0,4975
Lipetsk region / X3	7,2	82,1	6,4	79,0	6,4	83,5	8,2	86,1	8,5	75,1	-0,1844

Novgorod region / X5	5,7	96,1	5,5	74,2	5,8	74,9	9,3	73,4	9,8	70,9	-0,5057
Omsk region / X1	9,1	93,2	8,3	91,5	7,4	90,8	6,5	89,9	1,4	90,7	0,5252
Vladimir region / X7	3,8	16,1	3,2	15,7	2,9	16,5	3,2	15,8	4,3	15,5	-0,6013
Chelyabinsk region / X3	5,1	82,0	4,9	81,2	4,5	80,4	5,9	84,6	5,6	84,3	0,9840
Sverdlovsk region / X3	4,3	88,9	4,1	88,7	4,2	89,8	4,6	89,6	4,8	90,3	0,7558

* KSir – denotes the calculated coefficient of specialization by FEA of the region with the largest volume share in shipped products. CO2 – symbol of statistical indicator of the share of captured and neutralized air pollutants in the total amount of waste pollutants from stationary sources (in percent).
Source: compiled by the authors

The interpretation of the results of the obtained value of the correlation coefficient was carried out in accordance with the value of Pearson's R, which characterizes the level of relationship between the variables: 0.75 – 1.00 very high positive; 0.50 – 0.74 high positive; 0.25 – 0.49 medium positive; 0.00 – 0.24 weak positive; 0.00 – -0.24 weak negative; -0.25 – -0.49 medium negative; -0.50 – -0.74 high negative; -0.75 – -1.00 very high negative. At the same time, we note that if it is assumed that a strict order relation is set on the values of the variables, then a negative correlation is a correlation in which an increase in one variable is associated with a decrease in the other. Thus, having compiled correlation matrices for the specializations we have chosen, we can conclude that not all industrial regions have a strong direct correlation with the share of captured and neutralized air pollutants. The greatest positive impact on the environment is recorded in: Omsk region, where coke and petroleum products production shows a high and positive correlation with the share of captured and neutralized air pollutants; Chelyabinsk and Sverdlovsk regions, where metallurgical production has a very high positive correlation with the share of captured and neutralized air pollutants. These very industries, which are specialized in the above regions, belong to the medium-technology low-level production industry. The greatest negative impact was recorded in: Krasnoyarsk region, where metallurgical production has a medium negative relationship with the share of captured and neutralized air pollutants (it should be noted that such results can be largely due to the fact that the region specializes not only in manufacturing, but also in extractive industries); Novgorod region, where production of chemicals and chemical products, production of medicines and materials used for medical purposes has a high negative relationship with the share of captured and neutralized air pollutants; Vladimir region, where production of computers, electronic and optical products; production of electrical equipment has a high negative relationship with the share of captured and neutralized air pollutants.

5 Conclusion

Thus, regions whose production specialization is more high-tech have better environmental conditions. High-tech industries tend to be more environmentally friendly for several reasons. First, they often use resources more efficiently due to advanced technologies and production processes. For example, the use of advanced energy and materials management techniques can significantly reduce waste and energy consumption. Second, high-tech industries are often focused on innovation in environmental sustainability. This may include the development and implementation of new materials, processes, and technologies that are less stressful on the environment. Thus, the development of high-tech industries can encourage regions to diversify production and move towards more environmentally friendly production methods. This can lead to a reduction in negative environmental impact and an improvement in the quality of life. In the case of industrialized regions with a predominant share of metallurgy, it is important to undertake measures to update production processes and introduce environmental innovations. This may include modernization of equipment, introduction of waste recycling methods, use of cleaner and more efficient production technologies, and training of personnel in new working methods. Such efforts can not only reduce the negative environmental impact, but also help improve the competitiveness of regional enterprises by increasing production efficiency and reducing resource costs.

Acknowledgement

The article was prepared in accordance with the research plan for the Federal State Budgetary Institution of Science of the Institute of Economics of the Ural Branch of the Russian Academy of Sciences for 2024-2026.

References

1. I. Savelyeva, I. Danilova, A. Karpushkina, I. Kilina. Man. Sport. Medicine, **S1**, 141-152 (2021) DOI 10.14529/hsm21s122
2. D. Pletnev, V. Barkhatov. E3S Web of Conferences, **258**, 07044 (2021) DOI 10.1051/e3sconf/202125807044
3. D. Pletnev, A. Babkin, T. Levikova, A. Popova, L. Tashenova. E3S Web of Conferences, **389**, 02027 (2023) DOI 10.1051/e3sconf/202338902027
4. A. Salamatov, A. Davankov, A. Uzhegov. Bulletin of Omsk University. Series: Economics, **20(3)**, 140-153 (2022) DOI 10.24147/1812-3988.2022.20(3).140-153
5. I. Korshunov. Economics of the region, **1**, 15-28 (2023) DOI 10.17059/ekon.reg.2023–1-2
6. S. Grebenkina, E. Khrustalev, A. Slavyanov. Bulletin of Moscow University. Series 5. Geography, **1**, 63-72 (2020)
7. N. Kozyr. University Bulletin, **1**, 43-49 (2022) DOI 10.26425/1816-4277-2022-1-43-49
8. M. Brülhart. Weltwirtschaftliches Archiv, **137(2)**, 215-243 (2001) DOI 10.1007/BF02707264
9. A. Salamatov, A. Uzhegov. Bulletin of the Chelyabinsk State University, **11(481)**, 205-214 (2023) DOI 10.47475/1994-2796-2023-481-11-205-214.
10. E. Ryumina. Economics of the region, **12(4)**, 1113-1122 (2016) DOI 10.17059/2016–4–13
11. V. Tikunov, S. Belousov. Nauka. Innovation. Technologies, **1**, 89-106 (2021) DOI 10.37493/2308-4758.2021.1.6
12. M. Tengiz. (2021). Sustainable Development and Engineering Economics, **1**, 96-112 (2021) DOI 10.48554/SDEE.2021.1.6
13. A. Li. π-Economy, **6(137)**, 48-52 (2011)
14. J. Benedek, K. Temerdek-Ivan, I. Török, A. Temerdek, I. Holobaca. Sustainable Development, **29**, (2021) DOI:10.1002/sd.2180.
15. D. Bobin. Society: Politics, Economics, Law, **12**, 66-69 (2017)
16. A. Uzhegov. Bulletin of Omsk University. Series: Economics, **21(3)**, 118-128 (2023) DOI 10.24147/1812-3988.2023.21(3).118-128.