ECOLOGY AND NATURE MANAGEMENT

ASSESSING THE RELATIONSHIP BETWEEN ECONOMIC GROWTH IN RUSSIAN REGIONS AND ENVIRONMENTAL POLLUTION

SVETLANA S. PATRAKOVA
Vologda Research Center RAS
Vologda, Russian Federation
e-mail: sspatrakova@bk.ru
ORCID: 0000-0002-4834-3083; ResearcherID: B-5054-2019

DARYA S. PALKINA
Agency for Monitoring and Sociological Research
Vologda, Russian Federation
e-mail: palkina.darya2014@yandex.ru
ORCID: 0000-0002-3434-4173

In the context of the turbulence of the global economy and geopolitics, the task of ensuring accelerated economic growth of the regions by increasing the efficiency of using internal potential: natural resources, human resources, scientific and technological, etc. is strategically important for the Russian Federation. However, the solution to this problem, as noted by scientists and public administration practitioners, must necessarily take into account the environmental aspects of territorial development, current and future anthropogenic impact on the environment. Underestimation of these aspects can lead to irreversible consequences in the field of climate change, degradation of natural resources, deterioration of public health and reduction of the total economic potential of territories. The aim of the study is to assess the impact of environmental pollution on the economic growth of Russian regions. To achieve it, we used general scientific methods (generalization, analysis, synthesis) and methods of spatial econometrics (construction of multiple

regression models with spatial lags, calculation of local spatial autocorrelation indices). As a result, we found that, in general, in Russia's regions, an increase in the gross regional product is accompanied, on the one hand, by an increase in emissions of pollutants into the atmosphere from stationary sources and the number of passenger vehicles, and, on the other, by a decrease in discharges of contaminated wastewater into surface water bodies. The paper substantiates the clustering of regions in the country's space according to the level of per capita GRP and the most significant indicator of environmental pollution affecting it – emissions of pollutants into the atmospheric air. The paper proposes the directions of reducing emissions of such substances into the atmosphere. The results of the work contribute to the substantiation of the relationship between environmental factors and the economic growth of Russian regions and can be used by researchers in conducting research on similar topics, government authorities in the development of strategic documents and specific projects for the development of territories.

Region, economic growth, gross regional product, environmental pollution, ecology, spatial econometrics, emissions of pollutants into the atmosphere.

ACKNOWLEDGMENT

Introduction

The modern global agenda, based on the sustainable development concept[1], dictates the need to promote the economic and social spheres, taking into account the environmental component. This is clearly recognized not only by the scientific community (Zamyatina, 2021; Baraboshkina, Kudryavtseva, 2023; Bobylev et al., 2025, etc.), but also by representatives of state authorities and top officials of the country. For instance, according to Presidential Decree 309, dated 05/07/2024, one of the seven national development goals of the Russian Federation for the period up to 2030 and for the future up to 2036 is environmental well-being. In addition, environmental aspects related to reducing anthropogenic impact on nature are reflected in the vast majority of strategic planning documents at the federal level, including "non-core" ones, i.e. not directly related to solving environmental problems. For example, in the National Security Strategy of the Russian Federation, approved by Presidential Decree 400, dated 05/07/2024, environmental safety and rational use of natural resources are declared as a strategic national priority, the implementation of which, among other things, will contribute to the protection of the national interests of the country. In the Spatial Development Strategy of the Russian Federation for the period up to 2030 with a forecast up to 2036, approved by Government Resolution 4146-r, dated 12/28/2024, the main tasks of spatial development include the formation of territories of ecological well-being through the implementation of measures to preserve and restore the natural environment, ensuring the quality of the environment necessary for a comfortable and safe human life, as well as the sustainable development of the economy.

---

[1]   According to the definition of the International Commission on Environment and Development of the United Nations, sustainable development is a development that meets the needs of the present, but does not jeopardize the ability of future generations to meet their own needs. Source: Bobylev S.N. (Ed.). (2025). Fundamentals of Sustainable Development Economics. Moscow: Faculty of Economics, Lomonosov Moscow State University. 312 p. Available at: https://books.econ.msu.ru/economics-of-sustainable-development/sect01/chap02/2.1

However, despite the above, issues concerning the directions and scales of the relationship between environmental pollution indicators and economic growth of territories at various levels of the hierarchy remain controversial and poorly understood.

The aim of our study is to assess the impact of environmental pollution on the economic growth of Russian regions.

Achieving the goal involves solving two interrelated tasks:

– to propose a methodological approach to assessing the impact of environmental pollution on regional economic growth;

– to test the proposed approach and, based on it, assess the impact of environmental pollution on economic growth.

As part of these tasks, we are planning to test the research hypothesis that environmental pollution in the region affects economic growth not only in the region itself, but also in other Russia's regions.

Theoretical aspects of the research

The issues of identifying and assessing the relationship between economic growth and environmental pollution are controversial in the global scientific community. An analysis of the scientific literature allows dividing research on this issue into two large groups:

1) works devoted to the analysis of the impact of the level of economic growth on the ecological situation of territories at different levels of the hierarchy (countries, macro-regions and regions, local territories – urban municipalities, rural settlements, etc.);

2) works devoted to the analysis of the impact of environmental pollution indicators on the economic growth of territories at different levels of the hierarchy.

The studies of the first group are the most numerous. One of them is the work (Kilinc-Ata, Likhachev, 2022), which examines the relationship between carbon emissions and economic development factors such as economic growth, energy consumption, population, trade openness and financial development for the period 1990–2020 in relation to the Russian Federation. The key research method was the construction of a distributed lag autoregression model. Based on the results of its application, the authors concluded that to achieve zero carbon emissions by 2060, as part of the implementation of the climate policy of the Russian Federation, it is necessary to actively develop and apply environmentally friendly energy technologies, including on the basis of state support.

No less interesting is the work (Druzhinin et al., 2020), which reveals the reasons for the transformation of the relationship between economic and environmental indicators, examines the impact of changes in environmental legislation and other external shocks on environmental and economic processes in the Russian Federation and the European Union using the example of the air environment through the use of a variety of methods, including econometric modeling.

The work of V. Ivanova is devoted to the empirical assessment of the dependence of the level of environmental pollution on the level of GRP per capita in Russian regions, taking into account the features of their mutual spatial location through the use of tools of spatial econometrics, in particular, the calculation of the spatial autocorrelation of Moran (Ivanova, 2019).

The environmental consequences of the development of large industrial cities in resource-rich regions of Russia are discussed in the article (Pyzhev et al., 2021). Using the example of Krasnoyarsk, the authors show that during the implementation of resource megaprojects in the 20th century, the city became an important economic center of the Siberian macro-region. But the downside of this success has been environmental problems, primarily air pollution, which has become one of the main elements of the regional public agenda in recent years.

Some aspects of the influence of economic factors on environmental development and environmental pollution are described in the works of researchers from Omsk State Agrarian University (Golova, Gapon, 2022; Golova, Baranova, 2022), Samara National Research University and Perm State National Research University (Rostov, Cherepanova, 2020), as well as other scientific and educational organizations in the country. Foreign works on similar subjects include (Ekonomou, Halkos, 2023; Kulasinghe, Wijerathna, 2023; Chen, Tang, 2024).

Special attention should be paid to works that analyze the impact of various social, economic, and technological factors on the environment using special models such as IPAT, ImPACT, and STIRPAT. The IPAT model, developed back in 1971, is based on a multiplicative identity, according to which the environmental impact is equal to the product of population per capita and the intensity of emissions, depending on the technology used. Subsequently, other models were developed based on it, in particular the ImPACT model, which takes into account energy and carbon intensity factors. However, like IPAT, it could not be verified in terms of fulfilling statistical hypotheses. To remove this limitation, the STIRPAT model has been developed, which conceptually corresponds to IPAT, but is based on the use of regression analysis methodology. A detailed description of the IPAT, ImPACT, and STIRPAT models is described in the articles (Grigoryev et al., 2020; Mariev et al., 2021; York et al., 2003).

Among the works of the second group, a study (Porfir'ev et al., 2025) stands out which proposed a method for quantitative economic assessment of the consequences associated with permafrost degradation, floods, for economic facilities in the field of fuel and energy complex, agriculture and forestry. In the article (Kurbatskiy, Shakleina, 2022), based on spatial econometric models based on materials from the regions of Russia and the United States for the period 2004–2018. The existence of a spatial correlation in the level of pollutant emissions in the studied territories has been proved, and the hypothesis that the dependence of emissions on economic growth in Russian regions has the form of an inverted U-shaped curve has been confirmed. Among foreign works on the impact of environmental indicators on the economic growth of territories, one can single out, for example, an article (Acheampong, Opoku, 2023), in which materials from 140 countries for the period 1980–2021 revealed the retarding effect of environmental degradation on economic growth.

However, there are few works in which the above approaches are organically combined. Among them is a study by the staff of the Karelian Research Centre of the RAS (Druzhinin, Shkiperova, 2014), in which two problems were studied using statistical analysis and economic and mathematical modeling methods: the economic development impact on the environment and the impact of climate change on the development of certain economic sectors. As a result, it has been revealed that a significant part of Russian regions, in terms of the main indicators of environmental stress, is far from the maximum position on the Kuznets ecological curve[2], and potential economic growth in them may be accompanied by increased environmental degradation. This type of work abroad includes a study (Yan et al., 2022), which analyzes the nonlinear mechanism of the relationship between environmental pollution and economic growth in China using econometric modeling (construction of the MS-VAR autoregressive model).

---

[2] According to the Kuznets curve, with an increase in GDP (or GRP, when considering not the national, but the regional level) per capita, the volume of pollution per capita first increases and then decreases. That is, the connection has a U-shape.

Thus, we can conclude that the problem of the mutual influence of economic growth indicators and environmental pollution is in the focus of attention of Russian and foreign scientists. At the same time, the issues of the influence of economic factors on the state of the environment are more studied than the influence of environmental factors on economic growth. This creates a field for additional research. In addition, it is important to note that in the framework of such work, the most proven and proven method is econometric modeling.

Materials and methods

The information base of the study consists of Rosstat data on the volume of gross regional product as a result of economic growth, as well as on individual indicators of environmental pollution and economic development of 83 constituent entities of the Russian Federation[3] for the period 2014–2022. *Table 1* descibes the variables used in the study.

Table 1. Indicators used in the study

no	Indicator name, unit of measurement	Designation
	Endogenous variable	
1	Gross regional product (GRP), rubles per capita	GRP
	Exogenous variables of interest	
2	Emissions of pollutants into the atmospheric air from stationary sources, tons per capita	air_person
3	Discharge of polluted wastewater into surface water bodies, m3 per capita	water_person
4	Number of passenger cars owned by citizens, units per capita	pascar_person
5	Number of organizations using electronic data exchange, % of the total number of surveyed organizations	business
	Exogenous control variables	
6	Length of paved public roads, km per 1,000 people	road_person
7	Availability of fixed assets at the end of the year at full book value for the full range of organizations, thousand rubles per capita	fixAs_person
8	Level of innovation activity of organizations, % of the total number of surveyed organizations	innov

Note. When selecting exogenous variables, the presence of complete (without omissions) series of Rosstat statistical data in the territorial (by region) and temporal (by years from 2014 to 2022) sections was taken into account, which allows forming a balanced panel for regression analysis. Taking this aspect into account, from the limited set of environmental pollution indicators observed by Rosstat, the following were selected as variables of interest: 1) emissions of pollutants into the atmospheric air coming from stationary sources and discharges of polluted wastewater into surface water bodies as key indicators directly characterizing environmental damage and environmental pollution from the economic activities of the population; 2) number of passenger cars owned by citizens is one of the key indicators characterizing environmental damage from human activity (in the Russian Federation, the predominant number of cars have a gasoline engine, which during operation emits carbon dioxide and carbon monoxide, nitrogen and carbon oxides, etc. substances that contribute to the formation of smog, enhance the greenhouse effect, etc.); 3) number of organizations that have used electronic data exchange as one of the indicators, the growth of which, unlike those mentioned above, characterizes the reduction of environmental harm from economic activity (electronic exchange reduces the need for organizations for paper, printing and postal services, etc.). The choice of control variables designed to prevent a shift in coefficients for variables of interest is based on theoretical foundations and the results of previously conducted domestic research. Thus, in the Cobb–Douglas production function, which is used in When analyzing the regional economy, the indicator of the value of fixed assets is used as the "capital" factor (Suvorov et al., 2020). The influence of indicators of road transport infrastructure on GRP is justified, for example, in (Patrakova, 2025), and the level of innovation activity in (Shalaeva, 2022).
The indicators of per capita GRP and fixed assets were included in the model in a logarithmic form, since they are monetary (expressed in monetary units).
The reasons for the changes in the indicators used in modeling were not taken into account in this study (modification of the statistical accounting methodology in the period 2014–2022, changes in the range of observed or reporting enterprises, the introduction of new environmentally friendly technologies in certain regions of the country, etc.); they are the topic of future research.
According to: Rosstat data (collection "Regions of Russia. Socio-economic indicators" and its appendices. Available at: https://rosstat.gov.ru/folder/210/document/13204).

---

[3] Due to the lack of statistical data, information on the Donetsk People's Republic, Lugansk People's Republic, Zaporozhye and Kherson regions was not taken into account in the calculations.

The methodological approach to identifying and assessing the relationship between environmental pollution and economic growth in Russian regions is based on the construction of multiple regression models with spatial lags[4].

At the first stage, the basic descriptive statistics of the indicators selected for the study are analyzed. Multicollinearity between exogenous variables is checked, and variables with a strong relationship are excluded from further analysis, i.e. the correlation coefficient exceeds 0.7.

At the second stage, a multiple regression model is built on panel data. Taking into account the information given in Table 1, it has the following form:

$$\ln GRP_{it} = \beta_0 + \beta_1 \times air_{person_{it}} +$$
$$+\beta_2 \times water_{person_{it}} + \beta_3 \times pascar_{person_{it}} +$$
$$+\beta_4 \times business_{it} + \beta_5 \times road_{person_{it}} + \quad , (1)$$
$$+\beta_6 \times \ln fixAs_{person_{it}} + \beta_7 \times innov_{it} + \varepsilon_{it},$$

where:

GRP_{it} – GRP of i-th region in year t, rubles per capita;

air_person_{it} – emissions of pollutants into the atmospheric air from stationary sources in i-th region in year t, tons per capita;

$water\_person_{it}$ – discharge of polluted wastewater into surface water bodies in i-th region in year t, cubic meters per capita;

$pascar\_person_{it}$ – number of passenger cars owned by citizens of i-th region in year t, units per capita;

$business_{it}$ – number of organizations using electronic data exchange in i-th region in year t, % of the total number of surveyed organizations;

$road\_person_{it}$ – length of paved public roads in i-th region in year t, kilometers per 1,000 people of the population;

$fixAs\_person_{it}$ – availability of fixed assets at the end of the year at full book value for the full range of organizations in i-th region in year t, thousand rubles per capita;

$innov_{it}$ –level of innovation activity of organizations in i-th region in year t, % of the total number of surveyed organizations;

ε_{it} –accidental mistake;

β – regression coefficients.

It is important that the indicators selected for the analysis, namely the fact that none of them were unchanged during 2014–2022, allow building panel data models with both fixed and random effects (conditionally, if the first assumes that individual differences between regions are constants, then in the second they are random variables). At the same time, the choice of the best model among the constructed ones is based on a comparison of the Akaike and Schwartz information criteria.

Results and discussion

Descriptive statistics show that most of the variables selected for modeling have an uneven distribution, since the coefficient of variation in them exceeds 0.33 or 33% *(Tab. 2)*. However, due to the importance of the indicators for the study, as well as the need

---

[4]   In the most general sense, the spatial lag reflects the influence of the values of variables in neighboring spatial units (in this study, the RF regions) on the value of variables in the spatial unit under consideration. The simulation can take into account lag with a dependent variable (in this case, the model is called SAR), with unobservable variables/errors (SEM), with dependent variables and error (SAC), with dependent and independent variables simultaneously (SDM). The model, which includes all types of spatial interaction, has the abbreviation GSP.

to include in the model all regions of Russia for which statistics are available, it was decided continue working with the existing data set[5].

As part of the study of the selected indicators for multicollinearity, we found that all exogenous variables are characterized by weak and moderate correlation dependence (since the correlation coefficient is less than 0.7; *Tab. 3*), which allows them to be used for modeling.

It is worth noting that the highest degree of correlation among the analyzed seven indicators (correlation coefficient 0.6) was found between emissions of pollutants into the atmosphere from stationary sources and the availability of fixed assets. With a certain

degree of conditionality, this suggests that the key sources of atmospheric pollution in Russian regions are fixed assets, represented mainly by industrial enterprises, factories, and plants with an insufficiently high level of implementation of environmental-saving technologies.

Thus, all variables as a whole can be used to build a regression model of the impact of environmental pollution indicators on the gross regional product.

Within the framework of this study, 8 model specifications for panel data with fixed and random effects were constructed. *Table 4* presents their statistics and evaluation results. At the same time, a comparison of the Akaike and Schwartz information criteria made it

Table 2. Descriptive statistics of variables

Variable	Average value	Minimum	Maximum	Variation
GRP	671316.25	78009.30	11786365.00	1.60
air_person	0.16	0.00	2.40	1.84
water_person	83.05	0.24	542.81	0.85
pascar_person	0.32	0.04	0.61	0.23
business	58.89	24.5	91.1	0.15
road_person	9.38	0.51	28.69	0.47
fixAs_person	2101.18	23.79	36122.43	1.77
innov	9.93	0.18	33.76	0.54
Source: own compilation.				

Table 3. Correlation matrix of exogenous variables

Variable	road_person	air_person	water_person	business	pascar_person	innov	ln FixAs_person
road_person	1	-0.082	-0.134	0.022	0.123	-0.113	-0.086
air_person		1	0.090	-0.129	0.057	-0.135	0.556
water_person			1	0.134	0.146	-0.051	0.140
business				1	0.105	0.215	-0.040
pascar_person					1	0.142	0.370
innov						1	0.029
ln FixAs_person							1
Source: own compilation.							

---

[5] Otherwise, the possibility of excluding from the analysis those regions that produce "emissions" in certain indicators, such as the Nenets and Yamal-Nenets autonomous areas, whose per capita GRP is several times higher than the national average, would be considered.

possible to identify SAC as the best model with fixed effects, in which these criteria are minimal.

The data regarding the SAC model allows drawing the following conclusions.

1. The rho[6] spatial autocorrelation coefficient is statistically significant and positive, i.e. in the studied regions of the Russian Federation, the per capita GRP of each particular region is influenced not only by its "nearest neighbors", but also by more remote regions[7] (Demidova, Timofeeva, 2021).

2. The lambda[8] coefficient is also statistically significant, which confirms the need to take spatial effects into account (Dubovik, Dmitriev, 2025).

Table 5 shows more detailed descriptive statistics of the SAC model.

Table 4. Results of evaluation of panel data models with random and fixed effects

Indicator	Specification of models							
	With random effects				With fixed effects			
	SAR	SEM	SDM	GSP	SEM	SAR	SAC	SDM
Spatial autocorrelation coefficients								
Spatial								
rho	0.747***		0.687***			0.751***	0.879***	0.693***
lambda		0.919***		0.920***	1.022***		-0.651***	
phi				1.316***				
Variance								
lgt_theta	-2.532***		-2.508***					
sigma2_e	0.006***	0.006***	0.006***		0.005***	0.005***	0.004***	0.005***
ln_phi		3.841***						
sigma_mu				0.354***				
sigma_e				0.076***				
Akaike (AIC)and Schwartz (BIC) Information Criteria								
AIC	-1196	-995,4	-1224	-1022	-1451	-1745	-1834	-1770
BIC	-1145	-944,4	-1140	-965,9	-1410	-1703	-1787	-1695

Note: *** p-value < 0,01; ** p-value < 0,05; * p-value < 0,1. Dependent variable – l_GRP.
Source: own compilation.

Table 5. Regression estimates and spatial effects of the SAC model

Variable	Regression coefficient (β)	Direct effect (LR_Direct)	Indirect effect (LR_Indirect)	Total effect (LR_Total)
air_person	0.191***	0.282 ***	1.318***	1.600***
water_person	-0.000***	-0.001***	-0.003***	-0.003***
pascar_person	0.359***	0.537***	2.488***	3.025***
business	-0.000	-0.000	-0.001	-0.001
road_person	0.005	0.007	0.030	0.036
l_FixAs_person	0.051***	0.074***	0.342***	0.416***
Innov	0.000	0.000	0.001	0.001

Note: *** p-value < 0,01; ** p-value < 0,05; * p-value < 0,1.
Source: own compilation.

---

[6]   The coefficient before the spatial lag of the endogenous variable.

[7]   Demidova O.A. (2023). NAG Seminar "Assessment of the impact of macro shocks on socio-economic processes in Russian regions". Higher School of Economics. Available at: https://economics.hse.ru/mirror/pubs/share/824652359.pdf

[8]   Coefficient of spatial error autocorrelation.

An analysis of the data content in Table 5 allows drawing the following key conclusions regarding the impact of environmental pollution indicators on the gross regional product.

1. Emissions of pollutants into the atmospheric air from stationary sources are statistically significant within the framework of the model. With their increase, there is an increase in the per capita GRP of the region of these stationary sources. At the same time, they have a significant impact on the GRP of neighboring regions, and the effect is 4.67 times greater (0.282 versus 1.318).

The increase in GRP associated with an increase in emissions into the atmosphere from stationary sources is explained by an increase in the number of enterprises, most of which in the Russian Federation are manufacturing and extractive industries, or by an increase in utilization or capacity building of existing enterprises (an indirect sign of both the first and second options is an increase in pollutant emissions).

2. The rate of discharge of polluted wastewater into surface water bodies also turned out to be statistically significant. However, with its increase in the conditional ith region, there is a decrease in the per capita GRP of both this region and other regions of Russia. At the same time, the effect on other regions is 3.00 times higher than the effect on the first region (-0.001 versus -0.003).

The negative effect in this case is most likely due to a decrease in production volumes in agriculture, fishing and fish farming and other sectors of the economy as a result of such actions, as well as a deterioration in the quality of life, which is an important link in the GRP formation.

3. The number of passenger vehicles owned by citizens is also a significant factor for the region and increases its per capita GRP, while at the same time significantly affecting the GRP of neighboring regions (the effect is 4.63 times greater: 0.537 versus 2.488). At the same time, it is worth noting that it is the presence of motor vehicles that has the greatest positive impact on the GRP of each individual region of the country, and on the GRP of all other surrounding regions, as evidenced by the values of direct and indirect effects.

The increase in GRP as a result of an increase in the number of personal vehicles is due to the fact that the production of machinery requires the development of a large number of related industries (spare parts and components, the production of fuels and lubricants and the extraction of resources for their creation, etc.), services (insurance, etc.).

Thus, with an increase in emissions of pollutants into the atmosphere and the number of passenger vehicles in the conditional ith region of Russia, there is a positive GRP trend not only in this region, but also in other regions; with an increase in discharges into water, on the contrary, a negative GRP trend. The direct and statistically significant link between the increase in emissions of pollutants into the atmosphere from stationary sources and GRP, which indicates a low level of greening of production in the country, a high share of extractive and manufacturing industries in its economy, should attract the greatest attention of scientists, public administration practitioners, and the public. As noted by the Candidate of Sciences (Economics) A.R. Batchaev, industrial enterprises engaged in the production of chemical and metallurgical products, coke and petroleum products, rubber and plastic products, electricity, and enterprises producing oil and gas cause the greatest damage to nature[9]. This is confirmed by official statistical data: for example, on average in 2020–2022, oil and natural gas production accounted for 14.5% of total emissions of pollutants into the atmosphere substances *(Tab. 6)*.

---

[9] Industry vs ecology? HSE. Available at: https://spb.hse.ru/news/113729456.html

**Table 6. Emissions of air pollutants from stationary sources
by economic activity type in Russia**

Economic activity type	2020		2021		2022		On average in 2020–2022	
	thousand tons	% of the total volume	thousand tons	% of the total volume	thousand tons	% of the total volume	thousand tons	% of the total volume
Agriculture, forestry, hunting, fishing and fish farming	421.8	2.5	448.1	2.6	400.9	2.3	423.6	2.5
Mining	6754.8	39.8	6968.1	40.5	7235.0	42.1	6986.0	40.8
including coal mining	1379.1	8.1	1511.6	8.8	1434.6	8.4	1441.8	8.4
oil and natural gas production	2343.1	13.8	2599.3	15.1	2477.0	14.4	2473.1	14.5
mining of metal ores	2385.7	14.1	2129.2	12.4	2300.8	13.4	2271.9	13.3
extraction of other minerals	164.9	1.0	156.1	0.9	180.0	1.0	167.0	1.0
provision of services in the field of mining	482.1	2.8	572.0	3.3	842.6	4.9	632.2	3.7
Manufacturing industries	3900.5	23.0	3679.5	21.4	3606.7	21.0	3728.9	21.8
including food production	259.4	1.5	147.5	0.9	189.4	1.1	198.8	1.2
wood processing and manufacture of wood and cork products, except furniture, manufacture of straw products and materials for weaving	128.2	0.8	139.0	0.8	144.0	0.8	137.1	0.8
production of paper and paper products	75.8	0.4	71.4	0.4	72.0	0.4	73.1	0.4
production of coke and petroleum products	666.4	3.9	667.2	3.9	650.6	3.8	661.4	3.9
production of chemicals and chemical products	432.9	2.6	448.1	2.6	417.6	2.4	432.9	2.5
production of other non-metallic mineral products	425.9	2.5	469.2	2.7	538.4	3.1	477.8	2.8
metallurgical production	1499.6	8.8	1399.9	8.1	1282.2	7.5	1393.9	8.1
production of finished metal products, except machinery and equipment	37.8	0.2	40.1	0.2	37.2	0.2	38.4	0.2
manufacture of computers, electronic and optical products	40.1	0.2	32.2	0.2	32.2	0.2	34.8	0.2
manufacture of motor vehicles, trailers and semi-trailers	22.0	0.1	22.3	0.1	16.9	0.1	20.4	0.1
manufacture of other vehicles and equipment	34.5	0.2	43.4	0.3	52.4	0.3	43.4	0.3
Provision of electric energy, gas and steam; air conditioning	2890.9	17.1	3061.3	17.8	3114.1	18.1	3022.1	17.7
Water supply; sanitation, waste collection and disposal, pollution control activities	728.4	4.3	749.6	4.4	848.1	4.9	775.4	4.5
including water intake, purification and distribution	36.7	0.2	46.9	0.3	51.4	0.3	45.0	0.3
wastewater collection and treatment	66.7	0.4	77.2	0.4	90.3	0.5	78.1	0.5
collection, processing and disposal of waste; processing of secondary raw materials	623.1	3.7	623.7	3.6	703.2	4.1	650.0	3.8
provision of pollution control and other waste management services	1.8	0.0	1.9	0.0	3.2	0.0	2.3	0.0
Transportation and storage	1604.7	9.5	1675.6	9.7	1365.3	7.9	1548.5	9.1
According to: Rosstat data (appendix to the collection "Environmental Protection in Russia. 2024". Available at: https://rosstat.gov.ru/folder/210/document/13209).								

However, at the same time, enterprises of these types of economic activities create the bulk of GRP. This is confirmed, in particular, by the results of calculating the spatial autocorrelation index[10]. *Figures 1, 2* show cartograms of the distribution of 83 regions of Russia by cluster of the Moran scattering diagram in terms of per capita GRP and atmospheric emissions from stationary sources for 2022. It is clearly seen that the cartograms largely coincide. This is especially true for the extractive regions of the North and Siberia, and the Far East, in whose economic structure a significant share is occupied by the extractive and manufacturing industries, which have a significant negative impact on the environment.

The above determines the relevance and importance of reducing emissions of pollutants into the atmosphere from stationary sources while maintaining the pace of economic development. To solve this problem, it seems advisable to implement the following measures and directions with the cooperation of government authorities at the federal, regional and local levels, business, the scientific and educational community, the public and other interested parties.

1. Critical analysis, generalization and replication of advanced Russian and foreign experience in greening the industrial sector, especially in the manufacturing and extractive industries.

**Figure 1. Cartogram of Russian regions by Moran's index clusters
in terms of per capita GRP in 2022.**

Note. Here and in Fig. 2, the fill colors have the following designations:

	Cluster HH (regions have relatively high values of the analyzed indicator and are surrounded by the same regions)
	Cluster HL (regions have relatively high values of the analyzed indicator, but are surrounded by regions with relatively low values)
	LH cluster (regions have relatively low values of the analyzed indicator, but are surrounded by regions with relatively high values)
	LL cluster (regions have relatively low values of the analyzed indicator and are surrounded by the same regions)

Source: own compilation.

---

[10] The spatial autocorrelation index is calculated using a matrix of inverse distances across highways.

Figure 2. Cartogram of Russian regions by Moran's index clusters in terms of emissions of pollutants into the atmosphere from stationary sources in 2022
Source: own compilation.

Here we can highlight the experience of Nornickel in implementing the sulfur program starting in 2023, aimed at achieving sulfur capture rates at the level of world best practices at the Norilsk and Kola production sites and the complete elimination of emissions from the Kola Mining and Metallurgical Company[11]. The essence of the program is to create a new production site for the production of sulfuric acid from gases with a high sulfur dioxide content coming from the smelter of the Nadezhdinsky Plant. According to the conclusion of Rosprirodnadzor, all points of the Action Plan for achieving emission quotas by Nornickel have been fulfilled, and the effectiveness of gas purification has been confirmed (more than 99%). At the same time, the total amount of reduction in pollutant emissions in 2024 exceeded the established target values (fact – 386.5 thousand tons, plan – 377.6 thousand tons)[12].

It is also useful the experience of EVRAZ West-Siberian Metal Plant in building a structurally unique sulfur and gas purification complex, which will potentially reduce sulfur dioxide emissions into the atmosphere by 70%[13], at an agglomeration plant in Novokuznetsk.

No less interesting is the experience of RUSAL's development and implementation of the Ecological Soderberg technology, which made it possible to almost completely eliminate fluoride and benzapyrene emissions during aluminum production at the Krasnoyarsk Aluminum Plant[14]. The technology is an improved version of the traditional Soderbergh technology.

---

[11] The sulfur program. Available at: https://nornickel.ru/sustainability/projects/sulphur/

[12] Nornickel has confirmed the effectiveness of the Sulfur Program in Norilsk. Available at: https://nornickel.ru/news-and-media/press-releases-and-news/nornikel-podtverdil-effektivnost-raboty-sernoy-programmy-v-norilske

[13] Eiffel Tower in Siberia: a unique earthquake-resistant structure is being built for a factory in Novokuznetsk. Available at: https://наука.рф/news/eyfeleva-bashnya-v-sibiri-unikalnuyu-seysmostoykuyu-konstruktsiyu-stroyat-dlya-fabriki-v-novokuznets; In Kuzbass, the Eiffel Tower was completed at EVRAZ ZSMK. Available at: https://evrazsteel.ru/publication/news/eyfelevu-bashnyu-na-evraz-zsmk-dostroili

[14] Ecological Soderberg is a unique development of RUSAL. Available at: https://mnr-air.ru/tpost/637vxtoxn1-ekologicheskii-soderberg-unikalnaya-razr

However, special attention should be paid to the best available technologies, the incentives for the introduction of which have significantly weakened after the introduction of laxative environmental solutions for businesses in response to the Covid-19 pandemic and increased external sanctions pressure (Burmatova, 2023).

2. Expanding the list of cities participating in the federal Clean Air project[15], aimed at phasing down emissions of dangerous pollutants into the atmosphere through the implementation of comprehensive emission reduction plans; updating summary calculations of air pollution in the participating cities of the project; state support for the modernization of enterprises and laboratories of the Centers for Laboratory Analysis and Technical Measurements of Rosprirodnadzor, modernization and installation monitoring posts of the Russian Hydrometeorological Service; development of the laboratory control system of Rosprirodnadzor; implementation of environmental forecasting, modeling, analytics and artificial intelligence.

Initially, starting in 2018, the project was implemented in 12 cities that are industrial centers: Bratsk, where 30% of the country's aluminum is produced, Lipetsk and Magnitogorsk, specializing in ferrous metallurgy, Novokuznetsk, a metallurgical and coal mining center, etc. In 2023, 29 more cities joined them, mainly from the regions of Siberia and the Far East (Barnaul, Kemerovo, Minusinsk, Yuzhno-Sakhalinsk, etc.), bringing the total number of participating cities to 41. Two more cities, Salavat and Sterlitamak,

have begun implementing measures to reduce emissions under four-party agreements between government and business representatives. However, together these 43 cities make up only 3.8% of the total number in the country, which seems to be extremely insufficient.

In this regard, it seems relevant to expand the list of project participants by including not only industrial centers, but also cities that are important transport and logistics hubs, the cores of large and major urban agglomerations, as well as cities, urban-type towns and villages that are significant centers of agricultural production, etc.

3. Expanding the range of activities implemented within the framework of the federal Clean Air project. For instance, with regard to stationary sources, the possibility of providing grant support (on the terms of co-financing by interested enterprises) to researchers, scientists, designers, engineers for research, development and technological work aimed at reducing emissions into the atmosphere, as well as activities to introduce modern systems for automatic control of pollutants emissions of Russian production facilities.

With regard to non-stationary sources in million-plus cities, the cores of large and major urban agglomerations, the development of infrastructure for electric vehicles seems promising, which can potentially reduce the amount of pollutants emitted from personal vehicles, as well as the creation of a system of state financial or organizational support for owners of such vehicles. The construction of new and modernization, restoration of existing

[15] In 2018–2024, it was a part of the national Ecology project, and since 2025, it was a part of the national Environmental Well-being project (the Federal Clean Air Project. Available at: https://mnr-air.ru/about; Ministry of Natural Resources and Ecology of the Russian Federation. Available at: https://www.mnr.gov.ru/activity/environmental_well-being/federalnyy-proekt-chistyy-vozdukh).

trolleybus networks in cities, and expansion of the fleet of electric buses are relevant. The implementation of these measures should be carried out using methods and tools that do not duplicate the methods and tools of other government programs and projects (for example, the program "Development of the transport system"), or have a different geography.

Conclusion

The study assessed the relationship between GRP indicators and environmental pollution based on materials from 83 regions of Russia for the period 2014–2022. For this purpose, we propose a methodological approach, which is based on the tools of spatial econometrics, in particular, regression modeling based on panel data. Its application made it possible to identify the relationship between the level of per capita GRP (the resulting indicator of economic growth) of each region of Russia and environmental pollution indicators not only in it, but also in other regions, which indicates the need for state regulation of the environmental sphere mainly at the national rather than regional level.

The research results can be used by representatives of public authorities in improving the policy of territorial (spatial) development, and by researchers in overcoming the problems of the relationship between economic growth and the state of the environment.

REFERENCES

Acheampong A.O., Opoku E.E.O. (2023). Environmental degradation and economic growth: Investigating linkages and potential pathways. *Energy Economics*, 123, 106734. DOI: 10.1016/j.eneco.2023.106734

Baraboshkina A.V., Kudryavtseva O.V. (2023). External costs of road transport in the context of the transition to a low-carbon economy: Russian experience. *Vestnik Moskovskogo universiteta. Seriya 6: Ekonomika=Moscow University Economics Bulletin*, 3(58), 137–156. DOI: 10.55959/MSU0130-0105-6-58-3-7 (in Russian).

Bobylev S.N., Baraboshkina A.V., Kurdin A.A., Yakovleva E.Yu., Bubnov A.S. (2025). The national development goals of Russia and key sustainability indicators. *Vestnik Moskovskogo universiteta. Seriya 6: Ekonomika=Moscow University Economics Bulletin*, 1(60), 40–59. DOI: 10.55959/MSU0130-0105-6-60-1-3 (in Russian).

Burmatova O.P. (2023). Environmental regulation based on the best available technologies: Problems and trends. *Mir ekonomiki i upravleniya=World of Economics and Management*, 23(3), 21–34. DOI: 10.25205/2542- 0429-2023-23-3-21-34 (in Russian).

Chen Y., Tang J. (2024). The impact of economic growth targets on the level of green development-A perspective on officials' promotion incentives and environmental regulations. *Journal of Environmental Management*, 368, 122056. DOI: 10.1016/j.jenvman.2024.122056

Demidova O.A., Timofeeva E.A. (2021). Spatial aspects of wage curve estimation in Russia. *Zhurnal Novoi ekonomicheskoi assotsiatsii*, 3, 69–101. DOI: 10.31737/2221-2264-2021-51-3-4 (in Russian).

Druzhinin P.V., Shkiperova G.T. (2014). Assessment of mutual influence of economic and ecological processes. *Ekonomicheskie i sotsial'nye peremeny: fakty, tendentsii, prognoz=Economic and Social Changes: Facts, Trends, Forecast,* 2, 213–224. DOI: 10.15838/esc/2014.2.32.16 (in Russian).

Druzhinin P.V., Shkiperova G.T., Potasheva O.V., Zimin D.A. (2020). The assessment of the impact of the economy's development on air pollution. *Ekonomicheskie i sotsial'nye peremeny: fakty, tendentsii,*

prognoz=Economic and Social Changes: Facts, Trends, Forecast, 2, 125–142. DOI: 10.15838/esc.2020.2.68.8 (in Russian).

Dubovik M.V., Dmitriev S.G. (2025). Spatial effects in the distribution of cash incomes of Russia: Econometric analysis and regional policy recommendations. *KANT*, 14, 33–40. DOI: 10.24923/2222-243X.2025-54.6 (in Russian).

Ekonomou G., Halkos G. (2023). Exploring the impact of economic growth on the environment: An overview of trends and developments. *Energies*, 16(11), 4497. DOI: 10.3390/en16114497

Golova E.E., Baranova I.V. (2022). The role and influence of economic processes on the environment of Russia. *Fundamental'nye issledovaniya=Fundamental Researcher*, 4, 12–17. DOI: 10.17513/fr.43231 (in Russian).

Golova E.E., Gapon M.N. (2022). The impact of the economy on the ecological development of the region (on the example of the Omsk region). *Vestnik Altaiskoi akademii ekonomiki i prava*, 5–1, 11–16 (in Russian).

Grigoryev L.M., Makarov I.A., Sokolova A.K., Pavlyushina V.A., Stepanov I.A. (2020). Climate change and inequality: How to solve these problems jointly. *Vestnik mezhdunarodnykh organizatsii=International Organisations Research Journal*, 15(1), 7–30. DOI: 10.17323/1996-7845-2020-01-01 (in Russian).

Ivanova V. (2019). GRP and environmental pollution in Russia's regions: Spatial econometric analysis. *Kvantil'*, 14, 53–62 (in Russian).

Kilinc-Ata N., Likhachev V.L. (2022). Validation of the environmental Kuznets curve hypothesis and role of carbon emission policies in the case of Russian Federation. *Environmental Science and Pollution Research International*, 29, 63407–63422. DOI: 10.1007/s11356-022-20316-9

Kulasinghe D., Wijerathna I. (2023). *Effect of Economic Development on Environmental Pollution: A Comparative Analysis between Developed and Developing Countries.* Available at: https://www.researchgate.net/publication/384087669_Effect_of_economic_development_on_environmental_pollution_A_comparative_analysis_between_developed_and_developing_countries

Kurbatskiy A.N., Shakleina E.I. (2022). Economic growth and environmental pollution in the USA and Russia: Comparative spatial-econometric analysis. *Ekonomicheskie i sotsial'nye peremeny: fakty, tendentsii, prognoz=Economic and Social Changes: Facts, Trends, Forecast,* 2, 92–107. DOI: 10.15838/esc.2022.2.80.6 (in Russian).

Mariev O.S., Davidson N.B., Borzova I.A. (2021). The impact of urbanization on atmospheric pollution in Russian regions. *Zhurnal ekonomicheskoi teorii=Russian Journal of Economic Theory*, 18(4), 627–641. DOI: 10.31063/2073-6517/2021.18-4.11 (in Russian).

Patrakova S.S. (2025). The impact of road connectivity on economic growth of regions: Econometric modeling. *Ekonomicheskie i sotsial'nye peremeny: fakty, tendentsii, prognoz=Economic and Social Changes: Facts, Trends, Forecast,* 18(1), 89–105. DOI: 10.15838/esc.2025.1.97.5 (in Russian).

Porfir»ev B.N., Kolpakov A.Yu., Eliseev D.O. et al. (2025). Economic effects of climate change in Russia. *Problemy prognozirovaniya=Studies on Russian Economic Development*, 2, 20–36. DOI: 10.47711/0868-6351-209-20-36 (in Russian).

Pyzhev A., Sharafutdinov R., Zander E. (2021). Environmental consequences of the economic development of large industrial cities in resource regions (a case study of Krasnoyarsk, Russia). *EKO=ECO Journal*, 7, 40–55. DOI: 10.30680/ECO0131-7652-2021-7-40-55 (in Russian).

Rostova E.P., Cherepanova E.S. (2020). Analysis of the relationship between GRP and harmful emissions in the Volga Federal District. *Vestnik Samarskogo universiteta. Ekonomika i upravlenie=Vestnik of Samara University. Economics and Management*, 2, 151–156 (in Russian).

Shalaeva L.V. (2022). Innovative activity of Russian companies in the context of federal districts. *Ekonomika, predprinimatel'stvo i parvo=Journal of Economics, Entrepreneurship and Law,* 12(10), 2821–2834. DOI: 10.18334/epp.12.10.116299 (in Russian).

Suvorov N.V., Akhunov R.R., Gubarev R.V., Dzyuba E.I., Fayzullin F.S. (2020). Applying the Cobb-Douglas production function for analysing the region's industry. *Ekonomika regiona=Economy of Region*, 16(1), 187–200. DOI: 10.17059/2020-1-14 (in Russian).

Yan C., Li H., Li Z. (2022). Environmental pollution and economic growth: Evidence of SO2 emissions and GDP in China. *Frontiers in Public Health*, 10, 930780. DOI: 10.3389/fpubh.2022.930780

York R., Rosa E.A., Dietz T. (2003). STIRPAT, IPAT and ImPACT: Analytic tools for unpacking the driving forces of environmental impacts. *Ecological Economics*, 46, 3, 351–365. DOI: 10.1016/S0921-8009(03)00188-5

Zamyatina M.F. (2021). The ecological component of the social sector of the regional economy in the context of sustainable development. *Ekonomika Severo-Zapada: problemy i perspektivy razvitiya*, 4(67), 4–18. DOI: 10.52897/2411-4588-2021-4-4-18 (in Russian).

INFORMATION ABOUT THE AUTHORS

Svetlana S. Patrakova – Candidate of Sciences (Economics), Researcher, Vologda Research Center, Russian Academy of Sciences (56A, Gorky Street, Vologda,160014, Russian Federation; e-mail: sspatrakova@bk.ru)

Darya S. Palkina – Junior Researcher, Agency for Monitoring and Sociological Research (33, Kozlyonskaya Street, Vologda, 160000, Russian Federation; e-mail: palkina.darya2014 @yandex.ru)

ЛИТЕРАТУРА

Барабошкина А.В., Кудрявцева О.В. (2023). Экстернальные издержки от автомобильного транспорта в контексте перехода к низкоуглеродной экономике: российский опыт // Вестник Московского университета. Серия 6: Экономика. № 3 (58). С. 137–156. DOI: 10.55959/MSU0130-0105-6-58-3-7

Бобылев С.Н., Барабошкина А.В., Курдин А.А., Яковлева Е.Ю., Бубнов А.С. (2025). Национальные цели развития России и ключевые индикаторы устойчивости // Вестник Московского университета. Серия 6: Экономика. № 1 (60). С. 40–59. DOI: 10.55959/MSU0130-0105-6-60-1-3

Бурматова О.П. (2023). Экологическое регулирование на основе наилучших доступных технологий: проблемы и тенденции // Мир экономики и управления. Т. 23. № 3. С. 21–34. DOI: 10.25205/2542-0429-2023-23-3-21-34

Голова Е.Е., Баранова И.В. (2022). Роль и влияние экономических процессов на экологию России // Фундаментальные исследования. № 4. С. 12–17. DOI: 10.17513/fr.43231

Голова Е.Е., Гапон М.Н. (2022). Влияние экономики на экологическое развитие региона (на примере Омской области) // Вестник Алтайской академии экономики и права. № 5–1. С. 11–16.

Григорьев Л.М., Макаров И.А., Соколова А.К., Павлюшина В.А., Степанов И.А. (2020). Изменение климата и неравенство: потенциал для совместного решения проблем (на русском и английском языках) // Вестник международных организаций. Т. 15. № 1. С. 7–30. DOI: 10.17323/1996-7845-2020-01-01

Демидова О.А., Тимофеева Е.А. (2021). Пространственные аспекты оценки кривой заработной платы в России // Журнал Новой экономической ассоциации. № 3. С. 69–101. DOI: 10.31737/2221-2264-2021-51-3-4

Дружинин П.В., Шкиперова Г.Т. (2014). Оценка взаимовлияния экономических и экологических процессов // Экономические и социальные перемены: факты, тенденции, прогноз. № 2. С. 213–224. DOI: 10.15838/esc/2014.2.32.16

Дружинин П.В., Шкиперова Г.Т., Поташева О.В., Зимин Д.А. (2020). Оценка влияния развития экономики на загрязнение воздушной среды // Экономические и социальные перемены: факты, тенденции, прогноз. № 2. С. 125–142. DOI: 10.15838/esc.2020.2.68.8

Дубовик М.В., Дмитриев С.Г. (2025). Пространственные эффекты в распределении реальных денежных доходов населения России: эконометрический анализ и рекомендации для региональной политики // KANT. № 14. С. 33–40. DOI: 10.24923/2222-243X.2025-54.6

Замятина М.Ф. (2021). Экологическая компонента социального сектора экономики региона в контексте устойчивого развития // Экономика Северо-Запада: проблемы и перспективы развития. № 4 (67). С. 4–18. DOI: 10.52897/2411-4588-2021-4-4-18

Иванова В. (2019). ВРП и загрязнение окружающей среды в регионах России: пространственно-эконометрический анализ // Квантиль. № 14. С. 53–62.

Курбацкий А.Н., Шаклеина Е.И. (2022). Экономический рост и загрязнение окружающей среды в США и России: сравнительный пространственно-эконометрический анализ // Экономические и социальные перемены: факты, тенденции, прогноз. № 2. С. 92–107. DOI: 10.15838/esc.2022.2.80.6

Мариев О.С., Давидсон Н.Б., Борзова И.А. (2021). Моделирование влияния урбанизации на загрязнение атмосферы в российских регионах // Журнал экономической теории. Т. 18. № 4. С. 627–641. DOI: 10.31063/2073-6517/2021.18-4.11

Патракова С.С. (2025). Влияние автотранспортной связности на экономический рост регионов: эконометрическое моделирование // Экономические и социальные перемены: факты, тенденции, прогноз. Т. 18. № 1. С. 89–105. DOI: 10.15838/esc.2025.1.97.5

Порфирьев Б.Н., Колпаков А.Ю., Елисеев Д.О. [и др.] (2025). Экономические эффекты изменения климата в России // Проблемы прогнозирования. № 2. С. 20–36. DOI: 10.47711/0868-6351-209-20-36

Пыжев А., Шарафутдинов Р., Зандер Е. (2021). Экологические последствия развития крупных промышленных городов в ресурсных регионах (на примере Красноярска) // ЭКО. № 7. С. 40–55. DOI: 10.30680/ECO0131-7652-2021-7-40-55

Ростова Е.П., Черепанова Е.С. (2020). Анализ взаимосвязи ВРП и вредных выбросов в регионах ПФО // Вестник Самарского университета. Экономика и управление. № 2. С. 151–156.

Суворов Н.В., Ахунов Р.Р., Губарев Р.В., Дзюба Е.И., Файзуллин Ф.С. (2020). Применение производственной функции Кобба – Дугласа для анализа промышленного комплекса региона // Экономика региона. Т. 16. № 1. С. 187–200. DOI: 10.17059/2020-1-14

Шалаева Л.В. (2022). Оценка инновационной активности российских организаций в разрезе федеральных округов // Экономика, предпринимательство и право. Т. 12. № 10. С. 2821–2834. DOI: 10.18334/epp.12.10.116299

Acheampong A.O., Opoku E.E.O. (2023). Environmental degradation and economic growth: Investigating linkages and potential pathways. *Energy Economics*, 123, 106734. DOI: 10.1016/j.eneco.2023.106734

Chen Y., Tang J. (2024). The impact of economic growth targets on the level of green development-A perspective on officials' promotion incentives and environmental regulations. *Journal of Environmental Management*, 368, 122056. DOI: 10.1016/j.jenvman.2024.122056

Ekonomou G., Halkos G. (2023). Exploring the impact of economic growth on the environment: An overview of trends and developments. *Energies*, 16(11), 4497. DOI: 10.3390/en16114497

Kilinc-Ata N., Likhachev V.L. (2022). Validation of the environmental Kuznets curve hypothesis and role of carbon emission policies in the case of Russian Federation. *Environmental Science and Pollution Research International*, 29, 63407–63422. DOI: 10.1007/s11356-022-20316-9

Kulasinghe D., Wijerathna I. (2023). *Effect of Economic Development on Environmental Pollution: A Comparative Analysis between Developed and Developing Countries.* Available at: https://www.researchgate.net/publication/384087669_Effect_of_economic_development_on_environmental_pollution_A_comparative_analysis_between_developed_and_developing_countries

Yan C., Li H., Li Z. (2022). Environmental pollution and economic growth: Evidence of SO2 emissions and GDP in China. *Frontiers in Public Health*, 10, 930780. DOI: 10.3389/fpubh.2022.930780

York R., Rosa E.A., Dietz T. (2003). STIRPAT, IPAT and ImPACT: Analytic tools for unpacking the driving forces of environmental impacts. *Ecological Economics*, 46, 3, 351–365. DOI: 10.1016/S0921-8009(03)00188-5

ИНФОРМАЦИЯ ОБ АВТОРАХ

Светлана Сергеевна Патракова – кандидат экономических наук, научный сотрудник, Вологодский научный центр Российской академии наук (Российская Федерация,160014, г. Вологда, ул. Горького, д. 56а; e-mail: sspatrakova@bk.ru)

Дарья Сергеевна Палкина – младший научный сотрудник, Агентство мониторинга и социологических исследований (Российская Федерация, 160000, г. Вологда, ул. Козленская, д. 33; e-mail: palkina.darya2014@yandex.ru)