Examining the Impact of Economic Factors on Air Pollution of the Arctic Regions

Pavel Druzhinin[a]
Luzin Institute for Economic Studies of the Kola Science Center of the Russian Academy of Sciences, 24a Fersman Street, Apatity, Russia
pdruzhinin@mail.ru

Keywords: Arctic regions, air pollution, investments.

Abstract: The article examines the impact of economic development on the environmental performance of the Russian Arctic regions. A model was built and an assessment of the influence of factors determining the dynamics of air pollution was made. It was shown that during the economic downturn, the dynamics of industrial production determined the change in pollutant emissions. With the beginning of economic growth, pollution reduction continued due to the modernization of production, the transition to modern technologies with a significantly lower level of environmental stress. Environmental investments also had a significant impact, the dynamics of which was unstable. In the 2010s, the growth of investment in industry stalled, and pollution began to increase in some regions.

1 INTRODUCTION

There are five Arctic regions in the European part of the Russian Federation. The Murmansk Region and the Nenets Autonomous Okrug (NAO) are fully included in the Arctic Zone of the Russian Federation (AZRF), and in the Arkhangelsk Region, the republics of Komi and Karelia – only the northernmost municipalities.

A significant part of the economy of these regions is mining, in gross regional product (GRP) its share in the NAO reaches 86%, more than in any other subject of the Russian Federation. The extraction of minerals and their primary processing have a significant impact on the environment. For example, in Karelia, more than half of the emissions of pollutants into the atmosphere are accounted for by JSC Karelsky Okatysh, which mines iron ore and produces iron ore pellets. The mining sector suffered less than others during the crisis of the 1990s, and it quickly shifted to exporting its products. Oil, metals and raw wood were in demand on the European market. Already in the late 1990s, the growth of mining began. High revenues from the export of products made it possible to carry out technical re-equipment of enterprises, switch to modern technologies.

In the Arctic regions, paper production and metallurgy related to the processing of local resources are also developed, which also heavily pollute the environment. The recession in the manufacturing industry was much stronger, and growth began later, but the products of the two most important industries were also exported, due to exports, their financial situation improved markedly in the 2000s, and enterprises were able to begin modernizing their production.

The structure of the economy of the capitals of the regions changed in market conditions, industrial enterprises were closed, and new ones appeared outside the regional centers. As a result, the share of services grew and the role of energy increased, the share of which in the volume of their industrial production reached 50%. The use of coal and fuel oil led to large emissions of pollutants. Switching to gas as the main fuel has reduced emissions, but it is associated with the construction of gas pipelines and stretches in the region for decades. Electricity production in the 1990s did not decrease as much as in the manufacturing industry, but in the Republics of Komi and Karelia it remained at the level of 2000.

Various models have been proposed to assess the impact of economic development on the environment. In the 70s, the IPAT model was proposed, which

[a] https://orcid.org/0000-0001-5303-0455

considered three factors – population size, per capita production and technological level. It was also used to study Russian regions (Tretyakova, 2019). The STIRAT model was later built on its basis (Diets, Rosa, 1994; Geely, Mancinelli, Mazzanti, 2014). This model has been improved, and factors affecting the dynamics of pollution have been proposed, complementing the above. Further, the following factors were considered: the dynamics of the urban population, the level of urbanization, the dynamics of industrial production, the share of industry in GRP, the share of agriculture in GRP, the share of mining in GRP, energy consumption, energy consumption per unit of GRP and some others (Wang et al, 2021; Li et al, 2016).

As already noted, the economic downturn of the 1990s led to a noticeable decrease in pollution, and with the beginning of economic growth in the 2000s, pollution began to increase in most regions, but in some regions emissions of pollutants decreased due to changes in the structure of the economy and its modernization (Semyachkov, 2021). To assess the impact of economic development on the environment, special models were built, including econometric, balance, optimization and game models (Glazyrina, 2022; Tretyakova, 2014). Separate models were used for studies of the northern and Arctic regions (Klyuchnikova, 2021; Vasil'tsov, 2021).

The purpose of this article is to analyze the impact of industrial development on the dynamics of emissions of pollutants in the Arctic regions of the European part of the Russian Federation.

2 METHODOLOGY AND DATA

The research examined Rosstat data on the Arctic regions for 1990-2022 (Regiony ..., 2023). Most of the economic and environmental indicators of the regions are available on the Rosstat website https://rosstat.gov.ru, there are indexes of cost indicators, which allows, if necessary, to build data series at comparable prices. The following indicators were used in the course of the research: GRP and its structure, shipped industrial products, investments in the economy, investments in industry, fixed assets, environmental investments by type, environmental protection costs by type, air pollution and others. The Arkhangelsk Region and the NAO began to be listed separately in reference books only from 2006-2012, so calculations were carried out for the combined region.

To analyze the relationship between economic and environmental indicators for each region, graphs were drawn, changes in the dynamics of pollutant emissions were analyzed and hypotheses about possible dependencies were put forward. As a result, pollution functions were built for each region, which helped to understand the causes of environmental changes (Druzhinin, 2012):

$$E(t) = A \times X_1^{\mu}(t) \times X_2^{\nu}(t) \times X_3^{-\eta}(t) \qquad (1)$$

where: $E(t)$ - air pollution; $X_1(t)$ – a factor negatively affecting the environment; $X_2(t)$ – a factor that can both positively and negatively affect the environment; $X_3(t)$ – a factor reflecting environmental protection activities and positively affecting the environment; A, μ, η, ν – constant; t - year. Previous studies have shown that in the Russian Federation, every economic crisis greatly changes the dependence of environmental and economic indicators, which means that the period during which the resulting dependence persists is quite short. As a result, it is difficult to build dependencies with a large number of indicators.

Since almost all types of activities affect the environment, more often the analysis of ecological and economic processes is carried out according to GRP and indicators derived from it. In the Russian Federation, the influence of industry is decisive, approximately 85% of air pollution are accounted for by industry. Therefore, the change in the level of pollution depends primarily on the dynamics of industrial production.

Several factors can have both positive and negative effects. The construction of new industrial enterprises and the expansion of existing ones lead to an increase in pollution, the amount of which depends on the technological level of production. The result may be different when modernizing enterprises. The transition to modern technologies often leads to a reduction in environmental impact. Therefore, investments in the economy and investments in industry, depending on their orientation, can have the opposite effect.

Accordingly, part of the investment does not lead to growth, but to a decrease in pollution, and the final result depends on the ratio of investments of different directions. For models, there is a certain difficulty at the regional level related to the availability of data on the direction of investments, it is available only for all investments in fixed assets. Structural shifts in the economy can also lead to a decrease in pollution with an increase in the share of services.

Environmental protection reduces the amount of pollution, it is reflected by two indicators – environmental investments and current

environmental protection costs. In this case, investments in air protection and the costs of air protection are considered.

Data analysis has previously shown the importance of changes in economic policy for the relationship between environmental and economic indicators. As a result of economic crises and changes in economic policy to get out of them, new ecological and economic dependencies have been developing since 1992, 1999 and 2009. For developed countries, changes in environmental policy are also having a noticeable impact, and quite quickly. In the Russian Federation, the situation is different, the execution of decisions is postponed for years, often the initial severity of environmental restrictions disappears due to the decisions of the executive branch.

It should be noted that the pollution functions (1) constructed according to the previous period, which are related to previously made investment decisions, cannot be used to predict after another economic downturn. They are useful only for analyzing the period in which the obtained dependencies were active. The need to overcome the crisis leads to a significant change in economic policy, and the parameters of the pollution function associated with the pre-crisis period (1) must be adjusted.

2 RESULTS

As already mentioned, air pollution is mainly associated with industrial activities, other activities have little effect on this environmental indicator. Emissions are decreasing in all regions, but they have increased in some periods. There was a slight increase in the Murmansk region in 1995-1997. In the Republic of Karelia, their small growth began in 2015, in the Komi Republic they grew strongly in 1994 and in 2011-2013. In the Arkhangelsk region, emissions fell in the 1990s along with the decline of the economy, then the rapid development of the NAO industry began, and emissions continued to grow until 2010. Emissions in the NAO increased from 22 tons in 2000 to 282 tons by 2010, but fell to 156 tons in 2011. As a result, by 2012, emissions had decreased to the level of 2002.

The economic downturn of the 1990s was accompanied by a much smaller reduction in air pollution. As a result, the ratio of air pollution to industrial production (specific emissions) increased in the 1990s and began to decrease since 1997 in all regions (Fig. 1). The least environmentally friendly enterprises turned out to be more competitive in market conditions. Until 1997, specific emissions grew both relative to GRP and relative to industrial production. Then the specific emissions decreased, at first quite quickly, and then more slowly, and only in the Murmansk region continuously. In other regions, there was an increase in specific emissions from time to time, in the Arkhangelsk region – in 2006-2010, in Komi – in 2011-2013, in Karelia – since 2015.

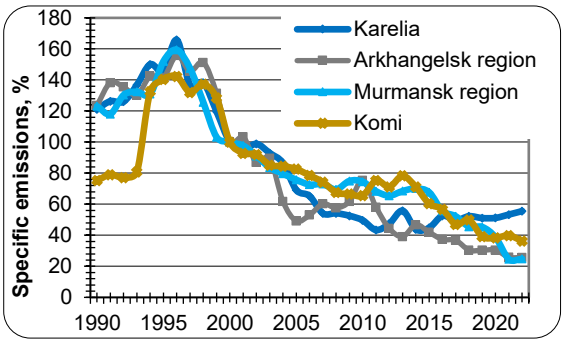

Figure 1: Dynamics of the ratio of pollutant emissions to industrial production, 2000=100%.

In the 1990s, the industry shrank by about half. The industry recovered fairly quickly in the 2000s and slowly in the 2010s. In the Murmansk Region, the Republics of Karelia and Komi, industrial production in 2022 was almost at the level of 1990, and air pollution was 2-5 times less, which most likely indicates the impact of modernization. In the 2010s, the industry of the regions practically did not grow, only in the Murmansk region since 2017 its rapid growth began, as a result of doubling investment in industry. The GRP of the three regions has so far reached only about 2/3 of the 1990 level.

The situation is slightly different in the Arkhangelsk region, whose industry grew rapidly in 2004-2010, when the oil fields of the NAO were being developed. Industrial production in the NAO has increased by more than 40% in some years. Accordingly, both industrial production and GRP in the Arkhangelsk region far exceeded the level of 1990.

Investments in the economy of the regions in the 1990s fell by 8-17 times, and there were no funds for the modernization of enterprises. In the 2000s, investments in the economy of all regions grew rapidly, and enterprises were modernized. In the 2010s, investment growth continued in the Murmansk Region, slowed down in Karelia, stopped in the Arkhangelsk Region, and investment began to decline in the Komi Republic. Investments in industry had a similar dynamic.

Investments in environmental protection vary significantly by region, in some years in the

Murmansk region they were about 200 times more than in Karelia. In the 1990s, the financial resources of enterprises were limited and environmental investments were rapidly declining. During the economic growth, the financial situation of enterprises improved, and for a short time environmental investments grew, then declined and grew again. Relative to 2000, environmental investments increased only in the Murmansk region, while in Karelia they decreased by 8 times. Investments in air protection decreased in all regions, in Karelia by 36 times in 2022 compared to 2000, and in some years there were no investments in air protection at all, which most likely was the reason for the increase in pollutant emissions in Karelia.

The analysis of the interrelationships of the indicators of the four regions in the graphs showed that for the three regions in the 1990s, the dynamics of pollutant emissions and industrial production are very close and equation (1) can have only one factor, which was confirmed by calculations (R^2=0.92-0.98). The decrease in environmental impact was less than the decline in production due to a decrease in environmental investments and negative structural shifts. In the Komi Republic in 1994, an environmental disaster occurred in Usinsk, which affected the dynamics of indicators and calculations for the 1990s were not carried out. Economic policy in the regions began to differ with the beginning of economic growth, respectively, the structure of the economy changed in different ways, environmental investments and modernization began to influence.

According to the collected data, calculations were carried out, which demonstrated the need to allocate three periods separated by the economic crises of 1998, and to a lesser extent 2008-2009. The graphs showed that the change in dependencies in 2008-2009 in the Komi Republic and the Murmansk region was small, for the Arkhangelsk region the most significant. At the same time, the change in environmental legislation has had virtually no effect on the dynamics of environmental and economic indicators of the four regions.

Table 1 and 2 shows the results of calculations, for the Arkhangelsk region it was necessary to allocate two periods and use the spline function. For the other three regions, calculations can be carried out for 1998-2021, which, however, is associated with a deterioration in statistical characteristics. Environmental investments turned out to be insignificant only in the 2010s for the Arkhangelsk region, their sharp decline affected. The Republic of Komi also found the importance of environmental investments to be low. Few industrial enterprises were built in the regions, they were often built near the regional center to replace enterprises with outdated technologies that were closed there, and on a new technological basis. Investments in industry were mainly aimed at modernizing existing enterprises, so investments led to a reduction in pollutant emissions. At the same time, the dynamics of investments in the economy reflected the potential increase in pollution better than GRP and industrial production.

Table 1: Results of calculations of pollution functions (1) for emissions of air pollutants in three Arctic regions for 1998-2021.

	Karelia	Komi	Murmansk Region
A	383.7***	804,3***	720,6***
Investments in the economy	0,069	0,569***	0,114
Investments in industry	-0,317*	-0,937***	-0,409*
Investments in the protection of the atmosphere	-0,042***	-	-
Environmental investments	-	-0,066	-0,120***
R^2	0,78	0,83	0,86
p	0,00000	0,00000	0,00000

*** p<0.01, * p<0.1

Table 2: Results of calculations of pollution functions (1) for emissions of pollutants in the Arkhangelsk region for 1998-2021.

	1998-2010	2011-2021
A	24,78***	0,0004***
Investments in the economy	0,986***	4,642***
Industry	-	0,942*
Investments in industry	-0,527***	-1,247***
Investments in the protection of the atmosphere	-0,142*	-
R^2	0,94	0,94
p	0,00000	0,00000

*** p<0.01, * p<0.1

4 CONCLUSIONS

The calculations carried out have shown the possibility of using pollution functions to identify factors affecting environmental pollution. During the recession until 1998, the dynamics of air pollution was determined by the dynamics of industrial production. Since 1998, other factors have also begun to influence, and the dependence of environmental

indicators on economic ones has become very different in the regions. Calculations for 1998-2021 confirmed the importance of modernization, which was the main factor in reducing air pollution. Environmental investments were also affected, which turned out to be insignificant for only one region in the 2010s. In the 2010s, investment growth slowed down and the transition to new technologies stalled, which led to an increase in pollution in some regions.

ACKNOWLEDGEMENTS

The publication was prepared within the framework of the state task of the Luzin Institute for Economic Studies KSC RAS (topic FMEZ-2023-0007).

REFERENCES

Dietz, T., Rosa, E. A., 1994. Rethinking the environmental impact of population, affluence and technology. *Human Ecology Review*. L. 1: 277–300.

Gilli, M., Mancinelli, S., Mazzanti, M., 2014. Innovation complementarity and productivity effects: Reality or delusion? Evidence from the EC. *Ecological Economics*. 103: 56–67.

Glazyrina, I.P., Lavlinskij, S.M., Yakovleva, L.L., 2022. Ekologo-ekonomicheskie modeli v mineralno-syrevom sektore Rossii: formirovanie investicionnoj politiki na osnove gosudarstvenno-chastnogo partnerstva. *Ekonomika i matematicheskie metody*. 58(3): 57-69. (In Russian).

Druzhinin, P.V., Shkiperova, G.T., 2012. Ecological and Economic Models and Predictions in the Regional Management System. *Studies on Russian Economic Development*. 23(1): 66-72.

Klyuchnikova, E. M., Korppoo, A., 2021. Implementation of the "green growth" concept in the Russian Arctic (on the example of the Murmansk region). *The Arctic: ecology and economics*. 11(4): 493-503. (In Russian).

Li, L., Lei, Y., He, C., Wu, S., Chen, J., 2016. Prediction on the Peak of the CO2 Emissions in China Using the STIRPAT Model. *Advances in Meteorology*. Article ID 5213623.

Regiony Rossii. Socialnj-ekonomicheskie pokazateli. 2023: Stat. sb. / Rosstat. 1122 p. (In Russian).

Semyachkov, A. I., Gao, R., Atamanova, E. A. 2021. Management of Regional Natural Resources based on the Variability of Environmental and Economic Indicators. *Economy of Regions*. 17(2): 520-537.

Tretyakova, E.A., 2019. Environmental intensity of economic growth in the Baltic Sea region. *Baltic Region*. 11(1): 14-28.

Tretyakova, E. A., 2014. Assessing Sustainability of Development of Ecological and Economic Systems: A Dynamic Method. *Studies on Russian Economic Development*. 25(4): 423-430.

Vasil'tsov, V. S., Yashalova, N. N., Novikov, A. V., 2021. Climate and environmental risks in the development of Arctic coastal territories. *The Arctic: ecology and economics*. 11(3): 341- 352. (In Russian).

Wang, M., Arshed, N., Munir, M., Rasool, S., Lin, W., 2021. Investigation of the STIRPAT model of environmental quality: a case of nonlinear quantile panel data analysis. *Environment, Development and Sustainability*. 23(2): 1-16.