ENVIRONMENTAL INTENSITY OF ECONOMIC GROWTH IN THE BALTIC SEA REGION

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National economic development is subject to a number of restrictions. One of the main constraints is the threat of complete exhaustion of non-renewable resources and environmental pollution exceeding the capacity of the planet. However, the rapid spread of resource-saving technologies is reducing the environmental intensity of economic activities. In this study, I aim to examine the ecological-economic dynamics of the environmental effects of economic development in the regions of Russia's North-Western Federal District (NWFD). I employ an extended version of Peter A. Victor's model to produce a comprehensive evaluation of changes in economic indicators and correlate them with the total and specific environmental impact. I conduct a factor analysis to identify the main effects influencing the ecological-economic dynamics. The use of water resources in the NWFD demonstrates green growth, whereas electricity consumption and wastewater treatment fall into the brown zone and industrial and municipal waste treatment into the black one. The factor analysis has shown that population change has a very weak effect on the situation. Much more influential factors are the income effect (higher incomes translate into greater consumption and thus more significant pollution levels) and the technology effect produced by a decrease in the environmental intensity of production. To promote green development, it is advisable to increase the influence of the technology effect by stimulating resource efficiency and switching to the circular economy model.

Keywords: sustainable development, green economy, economic growth, environmental pressure, North-Western Federal District, Russia

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Economic growth based on modern principles of management is accompanied by increased environmental pollution, the degradation of natural ecosystems, a reduction in biodiversity, the depletion of natural resources, climate change, and deteriorating public health. Today, the established philosophy and practices of management are no longer up to the task of improving the quality of life. There is a need for a change in priorities and for a transition to a new trajectory in line with the principles of sustainable development and the green economy. This trajectory will ensure economic growth focused on the needs of society, economic well-being, social justice, and providing a safe living environment rather than on obtaining the maximum economic benefit for a limited number of people through ruthless exploitation of natural and labour resources. Thus, environmental security is becoming crucial for economic development and the very existence of human society.

Environmental problems are global. Therefore, the green economy is a natural target for all countries. It is important to find an optimal balance between the needs of society for material and non-material goods and the natural resources of the earth to ensure that these goods can be produced. Here, technological innovations play a special role. They are necessary for a transition from fossil fuels to renewable energy, recycling, and reorganisation of industrial processes [1]. The modernisation of industrial production should embrace technological solutions that translate into efficient use of resources, a decrease in environmental pressure, and an increase in the quality of the environment.

The scientific community focuses on the benefits of green economic growth, which is aimed at creating new technologies and developing green industries. Moreover, green economic growth means new jobs, less poverty, and growing social responsibility of businesses. All this translates into better environmental performance and easier access to clean water and energy. The green growth concept can be applied to both developed and developing countries. However, it requires rethinking the general growth paradigm, since the current emphasis on quantitative growth has a detrimental impact on the environment and the preservation of natural resources for future generations. A new concept should be developed to ensure qualitative growth that is balanced in social, environmental and economic terms and embraces new ideas and innovations (see [2—6]).

In this study, I aim to investigate the ecological and economic dynamics of environmental effects associated with the economic development of one of Russia's leading macro-regions — the Northwestern Federal District (NWFD). The objectives of this research are as follows: 1) to justify my choice of a model and research methods, 2) to test these methods and model using the case of NWFD regions, and to 3) summarise and interpret the results obtained.

Theoretical approaches to assessing the environmental impact on economic development

Green economy relies on low-carbon and environmentally friendly production facilities that satisfy social and individual needs. While sparing the global ecosystem, these facilities preserve natural resources to pass them on to future generations for sustainable development. Thus, the overriding goal of the green economy is to move from high carbon to low carbon production and consumption. Scientific advances in technology have provided a wealth of opportunities for private and corporate businesses to move from resource-intensive and wasteful business models to resource-efficient and less energy-intensive ones [7].

Russian and international researchers have paid significant attention to measuring and evaluating these processes. Research literature describes various indices characterising the environmental impact of economic activities. Among them are the ecological footprint, the water footprint, the carbon footprint, and the living planet index.

Economic and mathematical methods and models are widely used in the green assessments of economic activities. In particular, it has been shown that innovation plays a big role in green growth and that R&D spending translates into lower carbon dioxide (CO_2) emissions in developed countries. In other words, not only is R&D spending a driver of growth in any economy but it also lends an impetus to sustainable development, where growth is accompanied by lower carbon monoxide emissions. This, among other things, encourages state regulatory bodies to invest in R&D and in combating climate change [8]. It has been emphasised that consumer awareness of environmentally friendly products has a positive effect on the formation of a green market and green entrepreneurship [9]. In addition, research has shown that the participation of trade unions is crucial for introducing more complex and radical innovations and reducing emissions [10].

A number of works consider different aspects of the problem. He et al. [11] estimate the effect of industrial dynamics and foreign direct investment on environmental performance. Mumtaz et al. [12] consider the relationship between changes in the main macroeconomic indicators and changes in electricity consumption. Tantau et al. [13] build a panel regression model to investigate the dependence between municipal recycling rates, materials recycling rates, R&D costs, trade volumes of processed raw materials, and revenues from environmental taxes. Smulders et al. [14] demonstrate that the greenness of an optimal growth path can depend heavily on initial conditions, with a variety of different adjustments occurring concurrently along an optimal path. Factor-augmenting technical-change targeting at offsetting resource depletion is critical to sustaining long-term growth within natural limits on the availability of natural resources and environmental services.

A. V. Polovyan and E. N. Vishnevskaya [15] focus on the problem of green development occurring in some countries at the expense of pollution in other countries. Economic and mathematical modelling has shown that the best results are achieved through a complex influence when regulation means encouragement and technology spillover into environmentally deprived areas to increase the overall efficiency of environmental protection activities. Another important incentive is strict sanctions stimulating both a change in the behaviour patterns of economic agents and the development of an innovative system capable of generating effective technological solutions to environmental problems.

V. V. Dmitriev and N. V. Kaledin [16] adopt an integrated approach to assessing the state of regional socio-ecological-economic systems. They reveal a tendency towards an increase in the quality of life in regions and suggest determining the stability of socio-ecological-economic systems using the critical values of integrated indicators, at which the system maintains its properties and parameters and remains within the same class of quality of life.

An important technique for the environmental assessment of economic growth is Peter A. Victor's model [17]. It uses one of the most common indicators of ecological intensity: carbon emissions per unit of GDP. Victor distinguishes green, brown, and black economic growth. His calculations show that the economic growth in Canada in recent decades was mainly brown. Victor's model, which is employed for comprehensive and dynamic assessments of economic indicators and their comparison with the total and specific ecological load, has been successfully tested and recommended by Russian scientists [18].

Index factor analysis is very productive in assessing the environmental intensity of economic activities. In particular, it is used to evaluate the contribution of various factors to the dynamics of energy intensity and greenhouse gas emissions from fuel combustion in energy generation [19, 20, 21]. However, the possible scope of its application is very wide.

In this study, I use factor analysis and an extended interpretation of Victor's model, which make it possible both to investigate the dynamics of volumetric economic indicators comparable with the volumetric and specific indicators of ecological load and to identify factors affecting ecological-economic dynamics.

The description of the research method

I propose to assess the environmental intensity of economic development in two steps. Firstly, one should determine the type of economic dynamics (the 'colour' of economic growth or recession) using Victor's model. Secondly, it is necessary to identify the most significant factors of economic dynamics by means of factor modelling. This approach makes it possible to establish what regulatory activities are required to support or adjust the current development trajectory.

Victor's model compares changes in the ecological-economic system using a certain point of reference, which is, as a rule, the beginning of the study period. At this point, the following indicators are recorded:

— the economic result (ER, gross domestic or regional product, production output, etc.);

— the ecological load (EL, the total amount of pollution produced [industrial and municipal wastes, emissions of air pollutants, discharge of polluted wastewater, etc.] or the total volume of consumed resources [electric or thermal energy, clean water, fuel resources, etc.]);

— the environmental intensity (EI) or resource intensity (the quotient of the ecological load divided by the economic result).

Below, I compare the values of the indicators with their initial values, determine their deviation, and identify the type of ecological-economic dynamics (Table 1).

Table 1

The type of ecological-economic dynamics [22]

Economic Result (ER)	Total Ecological Load (EL)	Envi-ronmental intensity (EI)	Characteristics of ecological-economic dynamics
Growth	Reduction	Reduction	Green growth
Growth	Growth	Reduction	Brown growth
Growth	Growth	Growth	Black growth
Recession	Growth	Growth	Black recession
Recession	Reduction	Growth	Green recession
Recession	Reduction	Reduction	Absolutely Green recession

Empirical studies show that most countries and regions have green and brown economic. In this vein, E. A. Lyaskovskaya and K.M. Grigorieva [23] carry out a comparative analysis of the brown and green economy models and demonstrate the negative consequences of choosing the brown economy model.

After obtaining the qualitative characteristics of the ecological-economic dynamics, I propose to identify factors that have the strongest impact on ecological-economic dynamics. I choose the factor model, since it displays the causal relationships between the indicators of ecological load, ecological intensity, and economic result. Therefore, the resultant model should reflect the dependence of the ecological load on the quantitative factor (for example, economic result) and the qualitative factor (ecological intensity).

A similar approach was used in [24]. However, it was applied solely to the effect of human factor on the scope of environmental impact:

$$I = P \cdot F, \quad (1)$$

I is the total value of the negative human impact on nature,

P is population (a quantitative factor),

F is a function measuring the environmental impact per capita (a qualitative factor).

This model, labelled *IPAT*, was applied in a modified form in [21, 25, and 26]. The scale of anthropogenic impact (I) depends on three factors: the population size (P), affluence (A) and technology (T):

$$I = P \cdot A \cdot T \quad (2)$$

For the purposes of this study, the *IPAT* model can be written as follows:

$$EL = P \cdot A \cdot EI, \quad (3)$$

where EL is the total value of the ecological load,

P is population (a quantitative factor),

A is affluence (a qualitative factor),

EI is the environmental intensity (a qualitative factor), which describes the technologies applied.

An evaluation of the impact of these factors on the ecological load makes it possible to carry out a quantitative assessment of the contribution of each factor as a combination of effects, namely:

— the population effect produced by population change (ΔP);

— the income effect resulting from a change in the welfare of the population (ΔW);

— the technology effect relating to changes in the environmental intensity as a result of changes in the technologies applied (ΔEI).

An evaluation of the environmental intensity of economic development in the NWFD regions

I tested the method discussed above using the case of one of Russia's leading macro-regions — the NWFD. I conducted my study in 2011—2015. All the necessary data for all the NWFD regions are available for this period. In my study, I relied on official statistics published on the website of the Federal State Statistics Service[1] and the report *On the state and environmental protection of the Russian Federation in 2016*.[2]

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[1] Regions of Russia. The main characteristics of the subjects of the Russian Federation. 2017: Stat. Sat, *Rosstat.*, 2017; Environmental protection in Russia. 2016: Stat. sb., *Rosstat.*, 2016.

[2] *On the state and environmental protection of the Russian Federation in 2016*, 2018, *available at:* http://www.mnr.gov.ru/docs/o_sostoyanii_i_ob_okhrane_okruzhayushchey_sredy_rossiyskoy_federatsii/gosudarstvennyy_doklad_o_sostoyanii_i_ob_okhrane_okruzhayushchey_sredy_rossiyskoy_federatsii_v_2016_/ (accessed 31.08.2018)

Gross regional product (GRP) in fixed (2015) prices was used as the measure of the economic result and GRP in fixed prices per capita as the affluence indicator. Carbon dioxide emissions, the volume of household and industrial waste, and the wastewater discharge were employed as the measures of the environmental load. The resource intensity was assumed as a combination of the electrical and water intensity of GRP.

Table 2 presents the characteristics of ecological-economic dynamics in terms of the environmental intensity and the resource intensity.

Table 2

The ecological-economic dynamics in the NWFD regions

Region	Ecological intensity			Resource intensity	
	Industrial and municipal waste	CO_2 emissions	Discharge to surface water	Electricity consumption	Freshwater use
Republic of Karelia	*brown*	*brown*	*brown*	green	green
Komi Republic	**black**	green	green	*brown*	green
Arkhangelsk region	**black**	green	green	*brown*	green
Vologda region	*brown*	green	green	*brown*	green
Kaliningrad region	**black**	green	*brown*	*brown*	green
Leningrad region	**black**	*brown*	*brown*	*brown*	green
Murmansk region	green	green	green	green	green
Novgorod region	**black**	*brown*	*brown*	*brown*	green
Pskov region	**black**	*brown*	*brown*	green	green
Saint Petersburg city	**black**	*brown*	*brown*	*brown*	green

As the table shows, the greatest success was achieved in rational water use: against the background of growing GRP, the use of fresh water reduced and the water-intensity of GRP decreased. In particular, the volume of recycled and reused water increased in the Arkhangelsk, Vologda, and Novgorod regions.

The waste management situation is extremely difficult. Everywhere (with the exception of the Murmansk region), the volume of wastes increased. In the Republic of Komi, the Arkhangelsk, Kaliningrad, Leningrad, Novgorod, and Pskov regions, and Saint Petersburg, the rate of increase in waste volumes significantly exceeded that in GRP. Therefore, the economic growth in the NWFD regions (with the exception of the Murmansk region) is extensive from the environmental perspective, since because it is accompanied by growing. Figure 1 compares the basic rates of changes in the real GRP and the volumes of industrial and municipal wastes generated in 2011 and 2015. The graph does not illustrate the indicators of the ecological-economic dynamics of the Arkhangelsk region, where the growth of the volume of industrial and municipal waste was extremely high, reaching 3615.6 % over the study period.

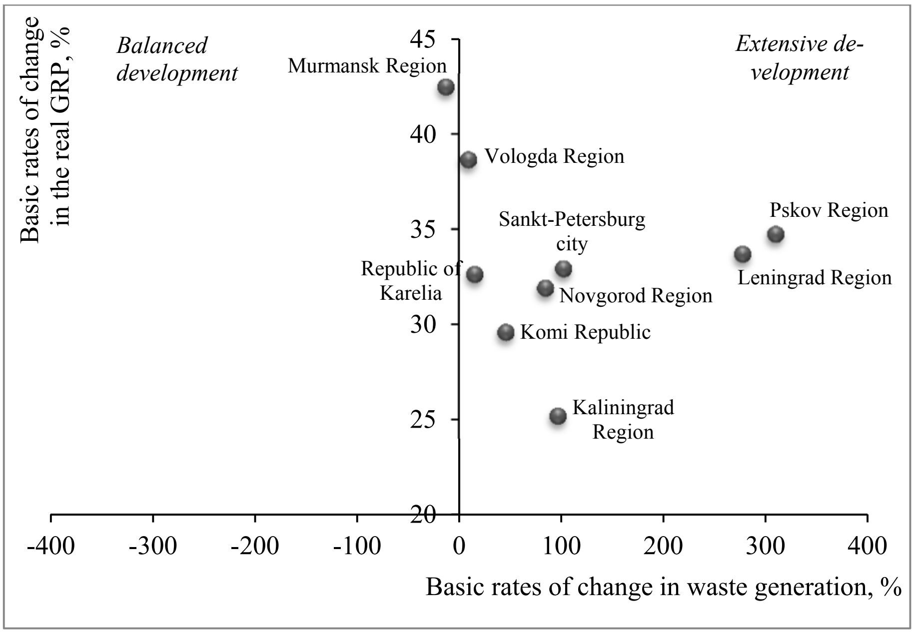

Fig. 1. GRP dynamics and industrial and municipal wastes generation in 2011—2015

A positive trend is a decrease in total and specific carbon dioxide emissions in the Komi Republic and the Arkhangelsk, Vologda, Kaliningrad, and Murmansk regions. A reduction in the total and specific volume of polluted wastewater discharge was observed in the Komi Republic and the Arkhangelsk, Vologda, and Murmansk regions.

An ecologically balanced change in all the indicators was observed in the Murmansk region, where GRP growth was accompanied by a decrease in both the total ecological load and the environmental intensity of economic activity. This was a result of structural shifts in the regional economy. In particular, the proportion of mining decreased by 3.9 %, of manufacturing industries by 3.7 %, and of energy by 0.2 %.

I analysed the factors behind these trends using the model discussed above (see formula [3]). In assessing the influence of these factors on pollution volumes, I employed the chain substitution technique, which is described in detail in [27, pp. 100—107]).

The analysis showed that the population effect associated with population change was observed in the study region. However, in all the cases, it was less marked than the other two. Further, I analysed the trends identified in the context of the income and technology effects. Tables 3—5 demonstrate the results of my analysis.

In all the cases, greater incomes were associated with stronger pollution. This may be explained by growing incomes leading to heavy consumption and thus, more substantial pollution. This situation is described by the ascending part of the Kuznets environmental curve (Fig. 2), when the achieved level of economic affluence is still insufficient for a massive change in the environmental behaviour of both consumers and producers. A similar conclusion has been made in some works on socio-ecological patterns in the Russian Federation (see, for example, [28]).

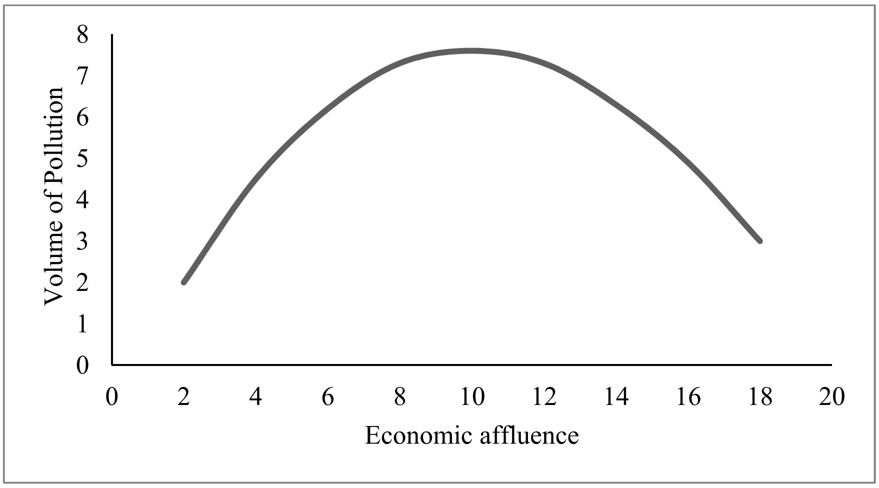

Fig. 2. Kuznets environmental curve [29]

As Table 3 shows, the stimulating effect of welfare growth on waste generation in the Murmansk region was compensated for by a dramatic reduction in the environmental intensity of production technologies. All this led to a decrease in both general and specific pollution.

In all the NWFD regions, the environmental intensity of technology was decreasing throughout the study period with respect to carbon dioxide emissions. Data shown in Table 4 suggest that the technology effect was stronger than the income effect was in the Komi Republic and the Kaliningrad, Pskov, and Arkhangelsk regions.

In all the study regions, the environmental intensity of technology decreased in relation to wastewater discharge. Data in Table 5 show that the technology effect prevailed over the income effect in the Komi Republic and the Arkhangelsk, Vologda, Novgorod, and Pskov regions, and Saint Petersburg. This led to a decrease in the total volume of polluted wastewater discharge.

A decrease in electricity consumption in the Republic of Karelia and the Pskov region is explained by the effect of the technology factor and the ensuing reduction in environmental intensity. An increase in electricity consumption across all the study area (with the exception of the Murmansk region) is accounted for by the affluence factor.

Table 3

The income and technology effects and industrial and household waste dynamics

Waste generation dynamics	region	Impact on wastes generation, 1,000 tonnes		
		Income effect	Technology effect	
		positive	positive	negative
Reduction	Murmansk region	99 487.0		–122 366.1
Growth	Republic of Karelia	38 585.0		–20 871.3
	Komi Republic	1 941.0	876.3	
	Arkhangelsk region	7 575.4	787 870.7	
	Vologda region	5 473.9		–4 244.6
	Kaliningrad region	93.4	296.9	
	Leningrad region	466.4	3 677.7	
	Novgorod region	409.5	617.3	
	Pskov region	53.7	388.7	
	Saint Petersburg city	1 037.0	2 595.5	

Table 4

The income and technology effects and the dynamics of carbon dioxide emissions

Dynamics of CO_2 emissions	region	Impact on CO_2 emissions, tonnes		
		Income effect	Technology effect	
		positive	positive	negative
Reduction	Komi Republic	70.9		–123.1
	Kaliningrad region	1.6		–2.1
	Murmansk region	9.7		–3.2
	Pskov region	3.9		–5.1
Growth	Republic of Karelia	4.6		–3.6
	Arkhangelsk region	44.7		–83.0
	Vologda region	107.0		–105.9
	Leningrad region	9.7		–3.2
	Novgorod region	6.3		–3.2
	Saint Petersburg city	4.9		–4.8

Table 5

The income and technology effects and surface discharge dynamics

Surface discharge dynamics	region	Effect on wastewater discharge, million m^3		
		Income effect	Technology effect	
		positive	positive	negative
Reduction	Komi Republic	43.1		–50.2
	Arkhangelsk region	129.2		–161.8
	Vologda region	62.1		–80.7
	Murmansk region	153.2		–144.9
	Novgorod region	31.4		–46.4
	Pskov region	17.0		–23.6
	Saint Petersburg city	337.1		–593.1
Growth	Republic of Karelia	59.8		–27.1
	Kaliningrad region	20.2		–10.9
	Leningrad region	71.0		–37.9

The dominant influence of the technology factor led to a decrease in clean water consumption across the NWFD regions.

Conclusion

The economy of the NWFD regions is becoming increasingly green. The ongoing technological change leads to greater resource efficiency and lower environmental intensity. This results in a reduction in carbon dioxide emissions and fresh water and energy consumption. However, new technology has not produced a fundamental change in the current development trajectory. It is necessary to employ best practices, particularly, in waste management. Stimulating recycling and the use of recyclables, ensuring greater presence in the world recyclables market, and promoting circular economy business models would have a positive effect on the economy and environment of Russia's North-West. Another important factor is environmental behaviour. Thus, growing affluence should go hand in hand with greater environmental awareness and the transformation of values from consumption to conservation. The literature shows (see [30]) that consumer awareness of environmentally friendly products has a positive effect on the formation of a green market and green entrepreneurship, as well as on sustainable development studies.

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