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Environmental taxes in ensuring national security: A structural optimization model

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Abstract. The purpose of the article is to assess the optimal ratio of environmental taxes in the context of national security. National security is defined as a complex parameter of indicators of economic, environmental and energy security, sensitive to the impact of environmental taxation, according to the method of Kolmogorov-Gabor. The environmental taxes with the greatest impact on the three identified components of national security have been

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selected. The sample of the study consisted of six European countries (Belgium, France, Austria; Finland and United Kingdom). The study covers the time period between 1994-2019. The optimization model of the structure of environmental taxes, which provides maximization of the level of national security, is built using the simplex method and the method of the general reduced gradient. The calculations allowed determining the optimal structural ratios of environmental taxes within each country thatachieves the maximum level of integrated national security. Besides, the strategic guidelines for adjusting national environmental taxation systems were developed to ensure national security.

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1. INTRODUCTION

Environmental sphere remains one of the crucial problems in the modern world community. The environmental sector requires sharp attention, as well as new and improved ways to ensure its effective functioning. The number of issues related to the need to be environmentally friendly is constantly growing due to the deteriorating impact of social processes and phenomena on the environment. Thus, environmental threats, such as depletion and destruction of available natural resources, pollution of the environment with artificial harmful substances, man-made disasters, environmental sabotage and others are very dangerous for further safe functioning of society (Chovancová, J., & Tej, J. 2020; Didenko et al., 2020; Dkhili, 2018). All this is exacerbated by political, legal, economic and social factors: imperfection of the legal framework for environmental law, insufficient efficiency of nature protection systems, improper organization of state control over the activities of entities that pollute or may adversely affect the environment, national economic situation, insufficient funding of the environmental sector, inefficient system of environmental taxation, unconscious environmental culture of society and others (Eddassi, H. 2020; Formankovaa, et al., 2018; He, 2019; Lyulyov et al., 2021). In turn, environmental threats significantly affect the general situation of the country, its safe functioning, the ability of public authorities to promptly intervene in emerging environmental problems, make necessary decisions and take appropriate action to address them effectively, determine the ability of people to consciously assess the importance of the environment. and the need to protect the environment (Masharsky et al., 2018; Sibanda & Ndlela, 2020; Starchenko et al., 2021; Vasylieva et al., 2021; Vysochyna et al., 2020b). Environmental security is closely linked to other types of national security, especially to the financial and economic sphere as one of the driving forces in ensuring overall national security and being able to provide adequate funding for the environmental protection through an effective system of measures, including environmental taxation. In turn, environmental taxes play a twofold role: on the one hand, a regulatory oneprovidings the ability to change the actions of those who harm the environment, and financially stimulate further rethinking and change of violators' behaviour, and on the other hand – a compensatory one, which will cover the damage and create a cushion of safety in case of possible economic and environmental losses.

2. LITERATURE REVIEW

General theoretical issues of national security are revealed in the works of world scientists (Samusevych et al., 2021; Mentel et al., 2020; Kubaienko, 2018; Didenko et al., 2021; Didenko et al., 2020a). They reveal the concept of security, describe the category of national security, its types, components, indicators, methods of achieving state security, describe threatening factors, determinants, features of the shadow economy, threats of bureaucracy, corruption and other issues. The transition of the world economy to a new technological system requires special consideration of the impact of the innovative economy on national security and the achievement of sustainable development goals. This direction has opened up new horizons for measuring the national security of the state in the global context (Amrin & Nurlanova, 2020; Kolosok et al., 2021; Lesakova, 2019; Medani, 2019; Mikhaylova et al., 2019). New challenges to national security have been created by the global Covid-19 pandemic. The first results of scientific research proved the existence of significant multiplicative links between certain areas of national security and testified to the need for its comprehensive study (Tiutiunyk et al., 2021; Antonyuk et al., 2021; Us et al., 2020).

Strong transmission effects are confirmed between social behavior and environmental security (Ahmed et al, 2019; Holotová et al., 2020; Vafaei et al., 2019) as well as entrepreneurial sustainable policy, which creates new prospects to enhance environmental and national security (Alimuddin et al., 2020; Atkociuniene & Mikalauskiene, 2019; Nikodemska-Wołowik et al., 2019; Romana, 2020; Vasylieva et al., 2017). Studies of the relationship between different types of national security have shown that the closest interaction exists in the group "environmental-energy-economic security" (Atta Mills et al., 2020). Thus, energy and environmental security are connected through the structure of energy production (Jonek-Kowalska, 2019; Kolosok et al., 2020), development of alternative energies (Cebula et al., 2018; Prokopenko et al., 2017), sustainable and green investment (Pavlyk, 2020). On the other hand, economic preconditions define the efficiency of environmental-energy interaction in terms of sustainable development strategies realizing (Cebula & Pimonenko, 2015; Vasilyeva et al., 2020a; Petrushenko et al., 2017). Thus, the achieved high level of macroeconomic stability creates reserves for the progressive transformation of the national economy in the direction of more environmentally responsible, eliminating threats to economic and energy security (Bilan et al., 2020; Fomina & Vynnychenko, 2017; Lyulyov et al., 2015; Melnyk et al., 2018). At the same time, the development of the financial sector creates favorable conditions for responsible investment in energy development and production restructuring using environmentally friendly technologies (Brychko et al., 2019; Lyeonov & Liuta, 2016).

The tasks of sustainable development require the interaction of economic agents at the level of the state, regions and individual industries, which will balance the manifestations of economic, environmental and energy security (Spremberg et al., 2017; Raszkowski & Bartniczak, 2018; Razminiene, 2019; Petrushenko et al., 2020; Kolosok et al., 2018). This approach requires finding tools that will ensure the optimal growth of various manifestations of national security, while maximizing its overall level and avoiding imbalances in its components. In addition, the development of tools for national security should take into account all possible structural changes in the national economy, which will achieve certain goals of the introduction of new instruments (Vasilyeva et al., 2019). The effectiveness of environmental, energy and economic security can be achieved through the use of a set of regulatory measures, especially financial and economic measures (Skare & Porada-Rochoń, 2019; Lyulyov et al., 2021a; Kouassi, 2018). And the most effective of them is the system of environmental taxation. That is, one of the most important methods is environmental taxes, which allow to implement the necessary regulation with minimal economic costs. The use of environmental taxes allows to perform environmental and compensatory functions. That is, on the one hand, it provides incentives for entities to rationally use and store resources, and on the other hand, to cover existing and possible losses from their unfair use or abuse. World experience demonstrates successful implementation of environmental taxes to achieve certain goals of national environmental policy (Miller, 2019).

The analysis of the existing literary achievements proves that the aspect of studying the field of ecology, and especially ecological taxation in terms of ensuring the security of the state, is still not sufficiently studied. This, in turn, does not allow to organize, formalize and sufficiently realize the existing financial potential of the environmental sector, as well as to ensure a sophisticated system of national security, which it directly affects. Synchronization of the goals of national policies of sustainable development and national security has led to an increase in the role of environmental taxes and the emergence of significant convergent trends in their dynamics (Vysochyna et al., 2020a). On the other hand, the process of transformation of tax policies of countries in the context of finding the most favorable operating conditions for national and international economic agents is incomplete (Boiko & Samusevych, 2017). This proves the importance of finding the optimal structure of the tax system that can maximize the effectiveness of tax policy. Accordingly, in the context of this study, the modeling of such a structure of environmental taxes, which maximizes the total effect of growth of the three components of national security (economic, environmental and energy).

3. METHODOLOGY

The methodology of building a multi-parameter model for optimizing the structure of environmental taxes in the context of national security involves the implementation of the following sequence of stages:

1 stage. Collection and processing of input statistical information in terms of optimizing the structure of environmental taxes in the context of national security. Substantiation of the indicators to be used to assess the components of national security (environmental, energy and economic security) was carried out in the works (Samusevych et al., 2021). The parameters of measurement national security were selected by testing their sensitivity to the impact of environmental taxes (using Granger Causality test).

Thus, environmental security indicators include: CO2 emissions, metric tons per capita; methane emissions, % change from 1990; nitrous oxide emissions, % change from 1990; fertilizer consumption, kilograms per hectare of arable land; total fisheries production growth, annual %; total greenhouse gas emissions, % change from 1990. Selected energy security indicators include: CO2 emissions from electricity and heat production, % of fuel combustion; CO2 intensity, kg per kg of oil equivalent energy use; electricity production from oil, gas and coal sources, % of total; energy imports, net % of energy use; combustible renewables and waste, % of total energy; energy use (kg of oil equivalent) per $1,000 GDP, constant 2011 PPP; fossil fuel energy consumption, % of total. Group of economic security indicators consists on: GDP growth, annual %;income share held by lowest 20%; industry (including construction) value added, annual % growth; current account balance, % of GDP.

The study included six countries (Belgium, Denmark, France, Austria, Finland and the United Kingdom) and covers 1994–2019. Analysis of the tax systems of each country allowed to select from two to nine environmental taxes that have the potential to simultaneously affect all three components of national security.

At this stage, in terms of interpolation of input statistics, gaps were processed using the method of average growth rate, in terms of extrapolation - forecasting the levels of time series by one of the methods of exponential smoothing by the Holt method:

$$\hat{y}_t(\tau) = a_{1,t} + a_{2,t} \cdot \tau \tag{1}$$

$$a_{1,t} = a_{1,t-1} + a_{2,t-1} + \alpha_1 \cdot e_t,$$

$$a_{2,t} = a_{2,t-1} + \alpha_2 \cdot e_t$$

where $\hat{y}_t(\tau)$ – the predicted value of the level of the series for the time interval τ, defined for t first levels;

$a_{1,t}$, $a_{2,t}$ - initial parameters of the Holt model, calculated by the method of least squares on the basis of data of the first few levels of the studied time series;

α_1, α_2 – smoothing parameters (take possible values within [0; 1]), are calculated by applying the method of multidimensional numerical optimization;

e_t - remnants of the model.

Stage 2. Construction of integrated assessments of environmental, energy and economic safety based on the use of additive-multiplicative convolution by the Kolmogorov-Gabor method. This method is based on:

2.1 Normalization of input indicators by the method of natural normalization for indicators-stimulators and Savage normalization for indicators-disincentives;

2.2 Taking into account the priority of component indicators in the formation of integrated assessments of environmental, energy and economic security based on the application of the method of analysis of hierarchies.

2.3 Carrying out nonlinear additive-multiplicative convolution of Kolmogorov-Gabor as integral indicators. This form of convolution allows to take into account the synergetic effect of interdependence of input indicators at their simultaneous influence as set. Additive-multiplicative convolution of Kolmogorov-Gabor takes the following form:

$$ECKG_{it} = \sum_{j} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\prod_{j}^{j+1} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\sum_{j+2}\prod_{j}^{j+2} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\sum_{j+2}\sum_{j+3}\prod_{j}^{j+3} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\sum_{j+2}\sum_{j+3}\sum_{j+4}\prod_{j}^{j+4} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\sum_{j+2}\sum_{j+3}\sum_{j+4}\sum_{j+5}\prod_{j}^{j+5} v_j \cdot \tilde{n}_{ijt} \quad (2)$$

where $ECKG_{it}$ – Kolmogorov-Gabor integrated indicator of the ecological component of national security in terms of the i-th country for the t-th year;

v_j – weighting factor of the j-th indicator;

$\tilde{n}_{ijt}$ – normalized value of the j-th indicator in terms of the i-th country for the t-th year.

$$ENKG_{it} = \sum_{j} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\prod_{j}^{j+1} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\sum_{j+2}\prod_{j}^{j+2} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\sum_{j+2}\sum_{j+3}\prod_{j}^{j+3} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\sum_{j+2}\sum_{j+3}\sum_{j+4}\prod_{j}^{j+4} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\sum_{j+2}\sum_{j+3}\sum_{j+4}\sum_{j+5}\prod_{j}^{j+5} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\sum_{j+2}\sum_{j+3}\sum_{j+4}\sum_{j+5}\prod_{j}^{j+5} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\sum_{j+2}\sum_{j+3}\sum_{j+4}\sum_{j+5}\sum_{j+6}\prod_{j}^{j+6} v_j \cdot \tilde{n}_{ijt} \quad (3)$$

where $ENKG_{it}$ – Kolmogorov – Gabor energy integral index component of national security in terms of the i-th country for the t-th year;

$$ECONKG_{it} = \sum_{j} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\prod_{j}^{j+1} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\sum_{j+2}\prod_{j}^{j+2} v_j \cdot \tilde{n}_{ijt} + \sum_{j}\sum_{j+1}\sum_{j+2}\sum_{j+3}\prod_{j}^{j+3} v_j \cdot \tilde{n}_{ijt} \quad (4)$$

where $ECONKG_{it}$ – Kolmogorov – Gabor integral index of economic component of national security in terms of the i-th country for the t-th year

Stage 3. Construction of the generalizing characteristic of the level of national security on the basis of application of additive-multiplicative convolution by the Kolmogorov – Gabor method:

$$NBKG_{it} = ENKG_{it} + ECKG_{it} + ECONKG_{it} + ENKG_{it} \cdot ECKG_{it} + ENKG_{it} \cdot ECONKG_{it} + ECKG_{it} \cdot ECONKG_{it} + ENKG_{it} \cdot ECKG_{it} \cdot ECONKG_{it} \quad (5)$$

where $NBKG_{it}$ – the level of national security of the country for the t-th year.

Stage 4. Construction of multiple linear and nonlinear ridge regression equations of dependence of the level of national security of six countries (Belgium, Denmark, France, Austria, Finland, Great Britain) on independent variables - shares of environmental tax revenues by types of total environmental taxes:

$$NBKG_{Bt} = b_0 + b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_1 \cdot x_2 \quad (6)$$

де $NBKG_{Bt}$ – the level of national security of Kolmogorov-Gabor for Belgium;
x_1 – the share of environmental charge in the total amount of environmental taxes;
x_2 – APETRA contribution share in the total amount of environmental taxes.

Models of national security dependence from environmental taxation structure for the others 5 countries are presented in Annex A.

Stage 5. Formalization of the optimization model of the structure of environmental taxes, which maximizes the level of national security through the application of the simplex method and the method of the general reduced gradient.

$$NBKG_{it} = f(x_1, \dots x_k, \dots, x_n) \rightarrow max \tag{12}$$

$$\begin{cases} x_1, \dots x_k, \dots, x_n \geq 0 \\ \min\limits_{k=1\div n} x_k + \sigma_k \leq x_k \leq \max\limits_{k=1\div n} x_k + \sigma_k \end{cases}$$

where $NBKG_{it}$ – the level of national security of the i-th country for the t-th year;

x_k – k-th variable, which takes values from 1 to n, and characterizes the share of the k-th type of tax in the total amount of environmental taxes;

$\min\limits_{k=1\div n} x_k$ – the minimum possible value of the share of the k-th type of tax in the total amount of environmental taxes for the study period;

$\max\limits_{k=1\div n} x_k$ - the maximum possible value of the share of the k-th type of tax in the total amount of environmental taxes for the study period;

σ_k – the standard deviation of the share of the k-th type of tax in the total amount of environmental taxes for the study period.

Stage 6. Spectral analysis of environmental, energy and economic security assessment for the optimal level of national security.

- for Belgium:

$$\begin{cases} ENKG_{it} = e_0 + e_1 \cdot NBKG_{it} \\ ECKG_{it} = c_0 + c_1 \cdot NBKG_{it} \\ ECONKG_{it} = d_0 + d_1 \cdot NBKG_{it} \end{cases} \tag{13}$$

- for Denmark, France and Austria

$$\begin{cases} ENKG_{it} = e_0 + e_1 \cdot NBKG_{it} \\ ECKG_{it} = c_0 + c_1 \cdot NBKG_{it} \\ ECONKG_{it} = d_0 + d_1 \cdot {NBKG_{it}}^2 + d_2 \cdot {NBKG_{it}}^3 + \\ +d_3 \cdot {NBKG_{it}}^{\frac{1}{2}} + d_4 \cdot \ln(NBKG_{it}) + d_4 \cdot \log(NBKG_{it}) + \dfrac{d_4}{NBKG_{it}} \end{cases} \tag{14}$$

- for Finland:

$$\begin{cases} ENKG_{it} = e_0 + e_1 \cdot NBKG_{it} \\ ECKG_{it} = c_0 + c_1 \cdot NBKG_{it} \\ ECONKG_{it} = d_0 + d_1 \cdot NBKG_{it}{}^2 + d_2 \cdot NBKG_{it}{}^3 + \\ +d_3 \cdot NBKG_{it}{}^{\frac{1}{2}} + d_4 \cdot \ln(NBKG_{it}) + d_4 \cdot \log(NBKG_{it}) + \dfrac{d_4}{NBKG_{it}} \end{cases} \quad (15)$$

- for the United Kingdom:

$$\begin{cases} ENKG_{it} = e_0 + e_1 \cdot NBKG_{it} \\ ECKG_{it} = c_0 + c_1 \cdot NBKG_{it} \\ ECONKG_{it} = d_0 + d_1 \cdot NBKG_{it}{}^2 + d_2 \cdot NBKG_{it}{}^3 + \\ +d_3 \cdot NBKG_{it}{}^{\frac{1}{2}} + d_4 \cdot \ln(NBKG_{it}) + d_4 \cdot \log(NBKG_{it}) + \dfrac{d_4}{NBKG_{it}} \end{cases} \quad (16)$$

4. EMPIRICAL RESULTS AND DISCUSSION

The construction of multiple linear and nonlinear ridge regression equations of dependence of the national security level of six countries on independent variables - shares of environmental tax revenues by type of the total amount of environmental taxes allowed to obtain results to assess the quantitative impact of individual environmental taxes and their combinations on national security. The evaluation was performed using the tools Statistica, Statistics / Multiple Regression for the case of linear models and Statistics / Advanced Linear / Nonlinear Models / Fixed Nonlinear Regression for the case of nonlinear models taking into account the Ridge Regression mark. The evaluation results obtained for Belgium are shown in Table 1.

Table 1

The results of statistical analysis of the dependence of the integrated national security index Kolmogorov-Gabor on the share of revenues from environmental taxes by type of the total amount of environmental taxes for Belgium for the period 1994-2019

Variable	Coefficient	Standard Error	t-stat	P > |t|	95% Confidence Interval	
Y-intercept	0,523	0,025	20,4213	8,61E-16	0,470	0,576
x1	29,657	125,190	0,236	0,814	-229,972	289,286
x2	7,938	2,630	3,017	0,006	2,482	13,394
x1x2	-807,159	4905,539	-0,164	0,870	-10980,6	9366,306

Source: own calculation

The results presented in the table allow us to assess the separate impact of each of the studied environmental taxes on national security while operating in the country's environmental tax system, and take into account the synergistic effects arising from the interaction of their impact on the integrated level of national security.

Based on the data in Table 1 for the example of Belgium, the objective function of the problem of optimizing the structure of environmental taxes in the context of national security is as follows:

$$NBKG_{Bt} = 0{,}523 + 29{,}657 \cdot x_1 + 7{,}938 \cdot x_2 - 807{,}159 \cdot x_1 \cdot x_2 \quad (17)$$

де $NBKG_{Bt}$ – the level of national security of Kolmogorov-Gabor for Belgium;
x_1 – the share of environmental charge in the total amount of environmental taxes;
x_2 – APETRA contribution share in the total amount of environmental taxes.

Generalizing models corresponding to equation (17) to describe the multiplex effect of combinations of environmental taxes on national security for other countries presented in Annex B. It should be noted that in systems with the simultaneous operation of more than two taxes, the impact of individual combinations of certain taxes, which are effective in assessing their separate impact, was also assessed. This allows maximizing their positive multiplex effects on the growth of national security and avoiding negative synergies through the simultaneous introduction of taxes, the combination of which poses a threat to national security.

Formalization of the optimization model of the structure of environmental taxes, which ensures the maximization of the level of national security was carried out using the simplex method (France, Finland) and the method of the general reduced gradient (Belgium, Denmark, Austria, Great Britain). For the example of Belgium, we will build an economic-mathematical multi-parameter model for optimizing the structure of environmental taxes in the context of national security:

$$NBKG_{Bt} = 0{,}523 + 29{,}657 \cdot x_1 + 7{,}938 \cdot x_2 - 807{,}159 \cdot x_1 \cdot x_2 \rightarrow max \quad (23)$$

$$\begin{cases} x_1, x_2 \geq 0 \\ 0{,}001024 \leq x_1 \leq 0{,}003588 \\ 0{,}013219 \leq x_1 \leq 0{,}050655 \end{cases}$$

Solving the optimization task (23) using the method of the general reduced gradient allowed to obtain the following results (table 2).

Table 2

The results of optimizing the structure of environmental taxes in the context of national security in Belgium

Indicator	Parameters of structural ratios of selected parameters of ecological taxes		Target function of the integrated level of national security
	x1	x2	
Optimal value	0,0134	0,0036	0,9057
Minimum value	0,0000	0,0000	0,3587
Maximum value	0,0024	0,0376	0,8586
Minimum value, corrected by standard deviation	0,0012	0,0138	0,4997
Maximum value, corrected by standard deviation	0,0034	0,0508	1,0000

Source: own calculation

Therefore, it is determined that the structural optimization of the environmental tax system in Belgium should provide for a reduction in the level of APETRA contribution while increasing revenues from environmental charge in the overall structure of environmental taxes. At the same time, a study conducted for Denmark (Table 3) showed that the structure of environmental taxes formed in the country is close to optimal in the context of national security. Thus, the obtained ratios provide only minor adjustments to maximize the multiplex effect of the estimated environmental taxes.

Table 3

The results of optimizing the structure of environmental taxes in the context of national security in Denmark

Indicator	Parameters of structural ratios of selected parameters of ecological taxes					Target function of the integrated level of national security
	x1	x2	x3	x4	x5	
Optimal value	0,0202	0,1731	0,0036	0,0009	0,0083	0,6988
Minimum value	0,0131	0,0988	0,0003	0,0000	0,0070	0,2471
Maximum value	0,0380	0,1542	0,0083	0,0008	0,0109	0,8368
Minimum value, corrected by standard deviation	0,0202	0,1178	0,0021	0,0002	0,0082	0,4102
Maximum value, corrected by standard deviation	0,0451	0,1731	0,0102	0,0010	0,0121	1,0000

Source: own calculation

The next country for evaluation was France (Table 4). The results show that in order to optimize the multiplexed impact of environmental taxes on national security at the same time in terms of its environmental, economic and energy components, it is advisable to make significant structural adjustments to their levels.

Table 4

The results of optimizing the structure of environmental taxes in the context of ensuring the national security of France

Indicator	Parameters of structural ratios of selected parameters of ecological taxes							Target function of the integrated level of national security
	x1	x2	x3	x4	x5	x6	x7	
Optimal value	0,0031	0,2221	0,0346	0,0346	0,0000	0,0002	0,0061	0,9962
Minimum value	0,0000	0,0000	0,0342	0,0036	0,0002	0,0099	0,0032	0,2489
Maximum value	0,0079	0,1654	0,0446	0,0153	0,0024	0,0132	0,0054	0,8265
Minimum value, corrected by standard deviation	0,0031	0,0567	0,0378	0,0073	0,0008	0,0108	0,0038	0,4224
Maximum value, corrected by standard deviation	0,0110	0,2221	0,0483	0,0190	0,0031	0,0142	0,0061	1,0000

Source: own calculation

It should be noted that the existing approaches to the collection of environmental taxes in Austria need significant adjustments in terms of maximizing their regulatory capacity to ensure national security

(Table 5). In particular, the role of recurrent car taxes should be significantly increased in order to achieve the optimal effect. At the same time, the rest of the taxes should be left in a balanced proportion.

Table 5

The results of optimizing the structure of environmental taxes in the context of ensuring the national security of Austria

Indicator	Parameters of structural ratios of selected parameters of ecological taxes					Target function of the integrated level of national security
	x1	x2	x3	x4	x5	
Optimal value	0,0566	0,6074	0,0056	0,0746	0,0815	0,9807
Minimum value	0,0400	0,1020	0,3608	0,0000	0,0814	0,3359
Maximum value	0,1060	0,5243	0,9223	0,3007	0,3737	0,8571
Minimum value, corrected by standard deviation	0,0566	0,1851	0,4746	0,0722	0,1389	0,4788

Source: own calculation

The results obtained for Finland (Table 6) also indicate that the predominance excise duty in the general structure will be optimal.

Table 6

The results of optimizing the structure of environmental taxes in the context of ensuring the national security of Finland

Indicator	Parameters of structural ratios of selected parameters of ecological taxes									Target function of the integrated level of national security
	x1	x2	x3	x4	x5	x6	x7	x8	x9	
Optimal value	0,0005	0,6600	0,0065	0,0020	0,0038	0,1100	0,0400	0,0069	0,0586	0,9794
Minimum value	0,0000	0,4739	0,0000	0,0010	0,0027	0,0772	0,0187	0,0035	0,0538	0,2982
Maximum value	0,0027	0,6658	0,0018	0,0040	0,0063	0,1807	0,0382	0,0148	0,0883	0,8491
Minimum value, corrected by standard deviation	0,0006	0,5378	0,0006	0,0020	0,0038	0,1113	0,0248	0,0069	0,0661	0,4490

Source: own calculation

At the same time, the system of environmental taxes formed in the United Kingdom can be considered close to optimal (Table 7).

Table 7

The results of optimizing the structure of environmental taxes in the context of national security in the United Kingdom

Indicator	Parameters of structural ratios of selected parameters of ecological taxes				Target function of the integrated level of national security
	x1	x2	x3	x4	
Optimal value	0,0241	0,0020	0,0250	0,1800	0,9862
Minimum value	0,0018	0,0000	0,0000	0,0000	0,3972
Maximum value	0,0742	0,0014	0,0283	0,1250	0,8615
Minimum value, corrected by standard deviation	0,0241	0,0006	0,0079	0,0412	0,5357
Optimal value	0,0965	0,0020	0,0361	0,1662	1,0000

Source: own calculation

Spectral analysis of the assessment of environmental, energy and economic security for the optimal level of national security revealed the following interdependencies between the components of national security.

- for Belgium:

$$\begin{cases} ENKG_{it} = -0{,}431 + 1{,}343 \cdot NBKG_{it} \\ ECKG_{it} = -0{,}225 + 1{,}078 \cdot NBKG_{it} \\ ECONKG_{it} = 0{,}956 - 0{,}988 \cdot NBKG_{it} \end{cases} \quad (24)$$

- for Denmark:

$$\begin{cases} ENKG_{it} = -0{,}135 + 1{,}056 \cdot NBKG_{it} \\ ECKG_{it} = 0{,}231 + 0{,}963 \cdot NBKG_{it} \\ ECONKG_{it} = 0{,}405 + 0{,}020 \cdot {NBKG_{it}}^{2} + 0{,}000043 \cdot {NBKG_{it}}^{3} - \\ -0{,}031 \cdot {NBKG_{it}}^{\frac{1}{2}} - 0{,}033 \cdot \ln(NBKG_{it}) - 0{,}076 \cdot \log(NBKG_{it}) + \dfrac{0{,}044}{NBKG_{it}} \end{cases} \quad (25)$$

- for France:

$$\begin{cases} ENKG_{it} = -0{,}142 + 1{,}050 \cdot NBKG_{it} \\ ECKG_{it} = -0{,}165 + 1{,}195 \cdot NBKG_{it} \\ ECONKG_{it} = 0{,}604 - 0{,}210 \cdot {NBKG_{it}}^{2} - 0{,}161 \cdot {NBKG_{it}}^{3} - \\ -0{,}243 \cdot {NBKG_{it}}^{\frac{1}{2}} - 0{,}045 \cdot \ln(NBKG_{it}) - 0{,}105 \cdot \log(NBKG_{it}) - \dfrac{0{,}033}{NBKG_{it}} \end{cases} \quad (26)$$

- for Austria:

$$\begin{cases} ENKG_{it} = 0{,}073 + 0{,}772 \cdot NBKG_{it} \\ ECKG_{it} = -0{,}236 + 1{,}133 \cdot NBKG_{it} \\ ECONKG_{it} = 0{,}582 - 0{,}079 \cdot {NBKG_{it}}^{2} - 0{,}087 \cdot {NBKG_{it}}^{3} - \\ -0{,}092 \cdot {NBKG_{it}}^{\frac{1}{2}} - 0{,}022 \cdot \ln(NBKG_{it}) - 0{,}051 \cdot \log(NBKG_{it}) - \dfrac{0{,}006}{NBKG_{it}} \end{cases} \quad (27)$$

-for Finland:

$$\begin{cases} ENKG_{it} = -0{,}233 + 1{,}104 \cdot NBKG_{it} \\ ECKG_{it} = -0{,}146 + 1{,}065 \cdot NBKG_{it} \\ ECONKG_{it} = 0{,}694 - 0{,}243 \cdot {NBKG_{it}}^{2} - 0{,}370 \cdot {NBKG_{it}}^{3} - \\ -0{,}124 \cdot {NBKG_{it}}^{\frac{1}{2}} - 0{,}007 \cdot \ln(NBKG_{it}) - 0{,}016 \cdot \log(NBKG_{it}) - \dfrac{0{,}032}{NBKG_{it}} \end{cases} \quad (28)$$

-for United Kingdom:

$$\begin{cases} ENKG_{it} = -0{,}274 + 1{,}134 \cdot NBKG_{it} \\ ECKG_{it} = 0{,}110 + 0{,}824 \cdot NBKG_{it} \\ ECONKG_{it} = 0{,}873 - 253 \cdot NBKG_{it}{}^{2} - 0{,}331 \cdot NBKG_{it}{}^{3} - \\ -0{,}115 \cdot NBKG_{it}{}^{\frac{1}{2}} + 0{,}021 \cdot \ln(NBKG_{it}) + 0{,}048 \cdot \log(NBKG_{it}) - \dfrac{0{,}097}{NBKG_{it}} \end{cases} \quad (29)$$

5. CONCLUSION

The study aims to substantiate and confirm the hypothesis of the formation of the optimal structure of environmental taxes, which maximizes the integrated effect of their impact on national security. Empirical calculations have shown that environmental tax systems in European countries have different levels of their multiplex effectiveness in the context of national security. Construction of optimization models allowed to identify vectors of change in the structure of environmental taxes, which will increase their integrated regulatory efficiency. At the same time, the spectral analysis revealed the transmission effects that occur between the three components of national security - environmental, economic and energy. All this creates a basis for improving national tax policies in terms of achieving the strategic goals of national security, as well as its individual components.

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ANNEXES

Annex A

$$NBKG_{Dt} = f_0 + \sum_{i=1}^{5} b_i \cdot x_i + x_1 \cdot \sum_{i=2}^{5} b_{i+4} \cdot x_i + x_2 \cdot \sum_{i=3}^{5} b_{i+7} \cdot x_i + x_3 \cdot \sum_{i=4}^{5} b_{i+9} \cdot x_i + b_{15} \cdot \prod_{i=4}^{5} x_i + b_{16} \cdot \prod_{i=1}^{3} x_i + \prod_{i=1,4} x_i \cdot \sum_{i=3,4} b_{i+14} \cdot x_i + b_{19} \cdot x_2 \cdot \prod_{i=2}^{4} x_i + \prod_{i=4,5} x_i \cdot \sum_{i=2}^{3} b_{i+18} \cdot x_i + b_{22} \cdot \prod_{i=1}^{4} x_i + \prod_{i=3}^{5} x_i \cdot \sum_{i=1}^{2} b_{i+22} \cdot x_i \quad (7)$$

where $NBKG_{Dt}$ – the level of national security of Kolmogorov-Gabor for Denmark;

x_1 – the share of the duty on coal in the total amount of environmental taxes;

x_2 - the share of the duty on electricity in the total amount of environmental taxes;

x_3 - the share of pesticide duties in the total amount of environmental taxes;

x_4- the share of the duty on tires in the total amount of environmental taxes;

x_5 - the share of sale of vehicle number plates in the total amount of environmental taxes.

$$NBKG_{Frt} = b_0 + b_1 \cdot x_1 \cdot x_2 + b_2 \cdot x_2 \cdot x_4 + b_3 \cdot x_1 \cdot x_2 \cdot x_3 + b_4 \cdot x_1 \cdot x_5 \cdot x_6 \cdot x_7 + b_5 \cdot x_2 + b_6 \cdot x_5 \cdot x_4 + b_7 \cdot x_2 \cdot x_3 + b_8 \cdot x_6 \cdot x_3 \quad (8)$$

where $NBKG_{Frt}$ - the level of national security of Kolmogorov-Gabor for France;

x_1 – the share of the CO2-related malus system for vehicle registration in the total amount of environmental taxes;

x_2 - the share of the contribution to electricity generators for public services they provide in the total amount of environmental taxes;

x_3- the share of the internal tax on final consumption of electricity in the total amount of environmental taxes;

x_4 – the share of the internal tax on natural gas in the total amount of environmental taxes;

x_5 - the share of production taxes in the total amount of environmental taxes;

x_6- the share of special fuel tax in foreign communities in the total amount of environmental taxes;

x_7- the share of the tax on electricity pylons in the total amount of environmental taxes.

$$NBKG_{At} = f_0 + \sum_{i=1}^{5} b_i \cdot x_i + x_1 \cdot \sum_{i=2}^{5} b_{i+4} \cdot x_i + x_2 \cdot \sum_{i=3}^{5} b_{i+7} \cdot x_i + x_3 \cdot \sum_{i=4}^{5} b_{i+9} \cdot x_i + b_{15} \cdot \prod_{i=4}^{5} x_i + b_{16} \cdot \prod_{i=1}^{3} x_i + \prod_{i=1,4} x_i \cdot \sum_{i=3,4} b_{i+14} \cdot x_i + b_{19} \cdot x_2 \cdot \prod_{i=2}^{4} x_i + \prod_{i=4,5} x_i \cdot \sum_{i=2}^{3} b_{i+18} \cdot x_i + b_{22} \cdot \prod_{i=1}^{4} x_i + \prod_{i=3}^{5} x_i \cdot \sum_{i=1}^{2} b_{i+22} \cdot x_i \quad (9)$$

where $NBKG_{At}$ - the level of national security of Kolmogorov-Gabor for Austria;

x_1- the share of duties on vehicles (based on fuel consumption) in the total amount of environmental taxes;

x_2 - the share of recurrent car taxes in the total amount of environmental taxes;

x_3 - the share of the tax on mineral oils in the total amount of environmental taxes;

x_4- the share of road pricing for trucks for the use of highways in the total amount of environmental taxes;

x_5 - the share of the wastewater fee in the total amount of environmental taxes.

$$\begin{aligned} NBKG_{Ft} = f_0 &+ \sum_{i=1}^{9} b_i \cdot x_i + x_1 \cdot \sum_{i=2}^{9} b_{i+8} \cdot x_i + x_2 \cdot \sum_{i=3}^{9} b_{i+15} \cdot x_i + x_3 \\ &\cdot \sum_{i=4}^{9} b_{i+21} \cdot x_i + x_4 \cdot \sum_{i=5}^{9} b_{i+25} \cdot x_i + b_{25} \cdot \prod_{i=1}^{3} x_i + \prod_{i=1,4} x_i \\ &\cdot \sum_{i=3,5} b_{i+23} \cdot x_i + \prod_{i=1,6} x_i \cdot \sum_{i=5,7} b_{i+25} \cdot x_i + \prod_{i=1,8} x_i \cdot \sum_{i=7,9} b_{i+27} \cdot x_i + \prod_{i=2,4} x_i \\ &\cdot \sum_{i=3,5} b_{i+29} \cdot x_i + \prod_{i=2,6} x_i \cdot \sum_{i=5,7} b_{i+31} \cdot x_i + \prod_{i=2,8} x_i \cdot \sum_{i=7,9} b_{i+33} \cdot x_i + \prod_{i=3,5} x_i \\ &\cdot \sum_{i=4,6} b_{i+35} \cdot x_i + \prod_{i=3,7} x_i \cdot \sum_{i=6,8} b_{i+37} \cdot x_i + b_{46} \cdot \prod_{i=3,8,9}^{3} x_i + \prod_{i=2,3,4} x_i \\ &\cdot \sum_{i=1,5} b_{i+46} \cdot x_i + \prod_{i=1,4,5} x_i \cdot \sum_{i=3,6} b_{i+46} \cdot x_i + \prod_{i=1,6,7} x_i \cdot \sum_{i=5,8} b_{i+45} \cdot x_i \\ &+ \prod_{i=2,5,6} x_i \cdot \sum_{i=4,7} b_{i+49} \cdot x_i + \prod_{i=2,7,8} x_i \cdot \sum_{i=6,9} b_{i+49} \cdot x_i + b_{57} \cdot \prod_{i=1,7,8,9} x_i \\ &+ \prod_{i=1,3,4,5} x_i \cdot \sum_{i=2,6} b_{i+56} \cdot x_i + \prod_{i=1,5,6,7} x_i \cdot \sum_{i=4,8} b_{i+56} \cdot x_i + b_{62} \cdot \prod_{i=1,6,7,8,9} x_i \\ &+ \prod_{i=2,4,5,6} x_i \cdot \sum_{i=3,7} b_{i+60} \cdot x_i + \prod_{i=2,6,7,8} x_i \cdot \sum_{i=5,9} b_{i+60} \cdot x_i + \prod_{i=2}^{6} x_i \\ &\cdot \sum_{i=4,8} b_{i+62} \cdot x_i \\ &+ \prod_{i=4}^{8} x_i \cdot \sum_{i=3,9} b_{i+65} \cdot x_i + \prod_{i=2}^{7} x_i \cdot (b_{70} \cdot x_1 + b_{71} \cdot x_8 + b_{72} \cdot x_1 \cdot x_9) + b_{73} \cdot \prod_{i=3}^{9} x_i \end{aligned} \quad (10)$$

where $NBKG_{Ft}$ - the level of national security of Kolmogorov-Gabor for Finland;

x_1 – the share of the fee for a fishing license in the total amount of environmental taxes;

x_2 - the share of excise duty on fuel and electricity in the total amount of environmental taxes;

x_3- the share of the nuclear energy tax in the total amount of environmental taxes;

x_4 - the share of the fee for oil losses in the total amount of environmental taxes;

x_5 - the share of the registration fee for vehicles in the total amount of environmental taxes;

x_6- the share of vehicle tax in the total amount of environmental taxes;

x_7- the share of the fee for the collection / treatment of municipal waste in the total amount of environmental taxes;

x_8- the share of the fee for nuclear waste in the total amount of environmental taxes;

x_9- the share of fees for water use in the total amount of environmental taxes.

$$NBKG_{UKt} = f_0 + \sum_{i=1}^{4} b_i \cdot x_i + x_1 \cdot \sum_{i=2}^{4} b_{i+3} \cdot x_i + x_2 \cdot \sum_{i=3}^{4} b_{i+5} \cdot x_i + b_{10} \cdot \prod_{i=3}^{4} x_i + \prod_{i=1,2} x_i \cdot \sum_{i=3,4} b_{i+8} \cdot x_i + b_{13} \cdot \prod_{i=2}^{4} x_i + b_{14} \cdot \prod_{i=1}^{4} x_i \quad (11)$$

where $NBKG_{UKt}$ - the level of national security of Kolmogorov-Gabor for United Kingdom;

x_1 – the share of payment for passenger air transportation in the total amount of environmental taxes;

x_2 - the share of the fee for the license of the organizer of air transportation in the total amount of environmental taxes;

x_3- the share of landfill tax in the total amount of environmental taxes;

x_4 - the share of renewable energy liabilities in the total amount of environmental taxes.

Annex B

$$NBKG_{Dt} = 0{,}189 + 0{,}046 \cdot x_1 + 1.635 \cdot x_2 - 1.230 \cdot x_3 + 29.263 \cdot x_4 - 18.273 \cdot x_5 + 4.708 \cdot x_1 \cdot x_2 - 60.235 \cdot x_1 \cdot x_3 - 4559.195 \cdot x_1 \cdot x_4 + 51.284 \cdot x_1 \cdot x_{85} + 77.079 \cdot x_2 \cdot x_3 + 362.114 \cdot x_2 \cdot x_4 + 73.115 \cdot x_2 \cdot x_5 + 15137.190 \cdot x_3 \cdot x_4 + 359.574 \cdot x_3 \cdot x_5 + 1185.873 \cdot x_4 \cdot x_5 + 716{,}484 \cdot x_1 \cdot x_2 \cdot x_3 - 356602{,}138 \cdot x_1 \cdot x_4 \cdot x_3 - 320256{,}943 \cdot x_1 \cdot x_4 \cdot x_5 + 124530{,}160 \cdot x_4 \cdot x_2 \cdot x_3 + 45475{,}906 \cdot x_4 \cdot x_2 \cdot x_5 + 1666511{,}259 \cdot x_4 \cdot x_5 \cdot x_3 - 1432823{,}059 \cdot x_1 \cdot x_2 \cdot x_3 \cdot x_4 + 14314468{,}365 \cdot x_5 \cdot x_2 \cdot x_3 \cdot x_4 - 14869402{,}174 \cdot x_1 \cdot x_5 \cdot x_3 \cdot x_4 \quad (18)$$

where $NBKG_{Dt}$ – the level of national security of Kolmogorov-Gabor for Denmark;
x_1 – the share of the duty on coal in the total amount of environmental taxes;
x_2 - the share of the duty on electricity in the total amount of environmental taxes;
x_3 - the share of pesticide duties in the total amount of environmental taxes;
x_4- the share of the duty on tires in the total amount of environmental taxes;
x_5 - the share of sale of vehicle number plates in the total amount of environmental taxes.

$$NBKG_{Frt} = 0{,}393 + 114{,}760 \cdot x_1 \cdot x_2 + 27{,}868 \cdot x_2 \cdot x_4 + 2495{,}541 \cdot x_1 \cdot x_2 \cdot x_3 - 415343255{,}965 \cdot x_1 \cdot x_5 \cdot x_6 \cdot x_7 + 0{,}629 \cdot x_2 + 13333{,}261 \cdot x_5 \cdot x_4 + 14{,}722 \cdot x_2 \cdot x_3 - 271{,}655 \cdot x_6 \cdot x_3 \quad (19)$$

where $NBKG_{Frt}$ - the level of national security of Kolmogorov-Gabor for France;
x_1 – the share of the CO2-related malus system for vehicle registration in the total amount of environmental taxes;
x_2 - the share of the contribution to electricity generators for public services they provide in the total amount of environmental taxes;
x_3- the share of the internal tax on final consumption of electricity in the total amount of environmental taxes;
x_4 – the share of the internal tax on natural gas in the total amount of environmental taxes;
x_5 - the share of production taxes in the total amount of environmental taxes;
x_6- the share of special fuel tax in foreign communities in the total amount of environmental taxes;
x_7- the share of the tax on electricity pylons in the total amount of environmental taxes.

$$NBKG_{At} = 0{,}474 - 0{,}414 \cdot x_1 + 0.497 \cdot x_2 - 0.334 \cdot x_3 + 0.582 \cdot x_4 + 1.087 \cdot x_5 + 0.986 \cdot x_1 \cdot x_2 - 1.295 \cdot x_1 \cdot x_3 + 1.263 \cdot x_1 \cdot x_4 + 3.503 \cdot x_1 \cdot x_5 - 0.007 \cdot x_3 \cdot x_2 + 0.490 \cdot x_4 \cdot x_2 + 0.441 \cdot x_4 \cdot x_2 + 0.143 \cdot x_3 \cdot x_4 + 0.110 \cdot x_3 \cdot x_5 + 0.5805 \cdot x_4 \cdot x_5 - 1.350 \cdot x_1 \cdot x_2 \cdot x_3 - 2.328 \cdot x_1 \cdot x_4 \cdot x_3 - 3.961 \cdot x_1 \cdot x_4 \cdot x_5 - 0.329 \cdot x_4 \cdot x_2 \cdot x_3 - 0.697 \cdot x_4 \cdot x_2 \cdot x_5 - 0.518 \cdot x_4 \cdot x_5 \cdot x_3 - 7.0033 \cdot x_1 \cdot x_2 \cdot x_3 \cdot x_4 - 1.918 \cdot x_5 \cdot x_2 \cdot x_3 \cdot x_4 - 10.046 \cdot x_1 \cdot x_5 \cdot x_3 \cdot x_4 \quad (20)$$

where $NBKG_{At}$ - the level of national security of Kolmogorov-Gabor for Austria;

x_1- the share of duties on vehicles (based on fuel consumption) in the total amount of environmental taxes;

x_2 - the share of recurrent car taxes in the total amount of environmental taxes;

x_3 - the share of the tax on mineral oils in the total amount of environmental taxes;

x_4- the share of road pricing for trucks for the use of highways in the total amount of environmental taxes;

x_5 - the share of the wastewater fee in the total amount of environmental taxes.

$$NBKG_{Ft} = 4.460 \cdot 10^{-1} \cdot x_1 - 3.351 \cdot 10^1 \cdot x_2 + 4.401 \cdot 10^{-1} \cdot x_3 - 3.281 \cdot x_4 - 1.443 \cdot 10^1 \cdot x_5 - 4.398 \cdot 10^{-1} \cdot x_6 + 7.166 \cdot 10^{-1} \cdot x_7 + 6.071 \cdot x_8 - 9.415 \cdot 10^{-1} \cdot x_9 - 1.658 \cdot 10^1 \cdot x_1 \cdot x_2 + 2.247 \cdot 10^4 \cdot x_1 \cdot x_3 - 6.401 \cdot 10^3 \cdot x_1 \cdot x_4 - 8.516 \cdot 10^3 \cdot x_1 \cdot x_5 - 3.342 \cdot 10^2 \cdot x_1 \cdot x_6 - 5.579 \cdot 10^2 \cdot x_1 \cdot x_7 + 1.036 \cdot 10^2 \cdot x_1 \cdot x_8 - 2.486 \cdot 10^2 \cdot x_1 \cdot x_9 + \cdots \quad (21)$$

where $NBKG_{Ft}$ - the level of national security of Kolmogorov-Gabor for Finland;

x_1 – the share of the fee for a fishing license in the total amount of environmental taxes;

x_2 - the share of excise duty on fuel and electricity in the total amount of environmental taxes;

x_3- the share of the nuclear energy tax in the total amount of environmental taxes;

x_4 - the share of the fee for oil losses in the total amount of environmental taxes;

x_5 - the share of the registration fee for vehicles in the total amount of environmental taxes;

x_6- the share of vehicle tax in the total amount of environmental taxes;

x_7- the share of the fee for the collection / treatment of municipal waste in the total amount of environmental taxes;

x_8- the share of the fee for nuclear waste in the total amount of environmental taxes;

x_9- the share of fees for water use in the total amount of environmental taxes.

$$NBKG_{UKt} = 0{,}486 + 0{,}015 \cdot x_1 - 2{,}835 \cdot x_2 + 0{,}063 \cdot x_3 + 0{,}235 \cdot x_4 + 449{,}900 \cdot x_1 \cdot x_2 - 36{,}278 \cdot x_1 \cdot x_3 + 7{,}717 \cdot x_1 \cdot x_4 - 821{,}175 \cdot x_2 \cdot x_3 + 580{,}790 \cdot x_2 \cdot x_4 - 9{,}235 \cdot x_3 \cdot x_4 + 9823{,}818 \cdot x_1 \cdot x_2 \cdot x_3 + 163{,}213 \cdot x_1 \cdot x_4 \cdot x_3 + 21305{,}181 \cdot x_4 \cdot x_2 \cdot x_3 + 386203{,}880 \cdot x_1 \cdot x_2 \cdot x_3 \cdot x_4 \quad (22)$$

where $NBKG_{UKt}$ - the level of national security of Kolmogorov-Gabor for United Kingdom;

x_1 – the share of payment for passenger air transportation in the total amount of environmental taxes;

x_2 - the share of the fee for the license of the organizer of air transportation in the total amount of environmental taxes;

x_3- the share of landfill tax in the total amount of environmental taxes;

x_4 - the share of renewable energy liabilities in the total amount of environmental taxes.