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THE USE OF ECONOMETRIC MODELS IN THE ANALYSIS OF THE VOLUME OF POLLUTANTS

Об'єктом дослідження є застосування економетричних моделей у аналізі обсягу забруднюючих речовин, випуску готової продукції та взаємозв'язку цих показників. Застосування існуючих моделей аналізу не дає реальної картини взаємозв'язків та факторів впливу. Одним з найбільш проблемних місць є те, що застосування існуючих методів не дає можливості здійснювати перспективний аналіз, а характеризує тільки стан об'єкта дослідження у ретроспективному аналізі.

При дослідженні були застосовані матричні рівняння міжгалузевої балансової моделі, метод найменших квадратів та степеневу регресію при складанні пошукових прогнозів.

Визначено, що проблема екологічної безпеки зумовлює необхідність зміни моделі розвитку задля того, щоб передбачити майбутнє і створити найбільш ефективні засоби виживання людства, окреслити шляхи і визначити принципи виходу з глибокої кризи. Обґрунтовано, що нова модель розвитку визначає сталий розвиток як форму цивілізаційного розвитку, а екологічну стійкість як основу екологічної безпеки. Доведено, що забезпечення відповідного рівня стійкості та екологічної безпеки потребує і певних витрат, ефектом від яких може бути не прибуток, а саме зменшення екологічно-негативних наслідків. На основі використання інструментарію економетрії (регресійний аналіз) визначено взаємозв'язок між екологічною стійкістю та показниками, які потенційно можуть впливати на рівень екологічної стійкості. Побудована регресійна модель демонструє обернену залежність між індексом стійкого розвитку та обсягом ВВП на душу населення та пряму залежність між витратами на охорону довкілля та EPI. На основі отриманих результатів автором зроблено висновок, що для забезпечення відповідного рівня екологічної стійкості провідну роль відіграє фінансовий чинник, а саме витрати на охорону довкілля. В результаті дослідження визначено пряму залежність між валовим випуском продукції та обсягом забруднюючих речовин, який характеризує коефіцієнт кореляції 0,795. А також доведена достовірність 95 % регресійної залежності викидів в атмосферне повітря від обсягу сукупного випуску продукції.

Ключові слова: *екологічний розвиток, екологічна безпека, навколишнє середовище, регресійна модель, рівень забруднюючих речовин.*

1. Introduction

Non-renewable natural resources are gradually coming to an end, the regenerative natural resources are degraded as a result of their excessive use, the environment is polluted, the incidence of the population is increasing, which is associated with a poor environmental situation. Environmental pollution occurs quickly and «inexpensively», while the process of its recovery is slow, complex and requires significant financial resources. The degradation of the natural environment slows down socio-economic development.

So, the objective requirements of modernity is forming a new model of development, which, on the one hand, provides the appropriate conditions for the life of humanity at this stage and do not create threats to the existence of future generations. Most of the values of the XX century are less important than the values associated with environmental safety. After all, environmental security is associated with the possibility of life, its preservation, not only for present generations, but also for future generations. If, as a result of coordinated actions, the biosphere is preserved, then it will be possible for the civilization to survive and its continuous development not only during the next centuries, but also for the next indefinite period of time. In this regard, it is important to define environmental sustainability in conditions of sustainable development as the basis for environmental safety, which can decisively influence the future of each country in the world community. And also play an important role in determining state priorities, the strategy of socio-economic development and the prospects for further reform of the country.

2. The object of research and its technological audit

The realities of human development have proved that it is impossible to separate social and economic development and environmental security. It is necessary to establish a certain balance between the pleasure of modern needs of mankind, the goals of individual business entities and the interests of future generations, including their need for a safe, healthy environment. Therefore, *the object of research* is the use of econometric models in the analysis of the volume of pollutants, the release of finished products and the interrelation of these indicators.

One of the most problematic places is that the application of existing methods does not provide the opportunity to carry out a forward-looking analysis, and characterizes only the state of the object of research in a retrospective analysis. That is, it does not give a real picture of the interrelations and influencing factors.

3. The aim and objectives of research

The aim of research is determination of the impact of the output volume, GDP and their interrelationship with the aim of predicting the environmental consequences of industrial activities.

To achieve this goal, it is necessary to perform the following tasks:

1. To determine the amount of pollutants in the environment associated with production activities.

2. To determine the factors of influence on environmental sustainability and to detail the regression model with a view to a more detailed study of the factors influencing the state of the environment.

3. To build a regression model as a factor in the impact on pollution levels.

4. Research of existing solutions of the problem

The issue of environmental sustainability and sustainable development is studied in [1–4]. And the question of the financial side of ensuring an appropriate level of environmental sustainability is considered in [5, 6].

The works of the authors [7, 8] have considerable theoretical and practical value, but these works can not be used at industrial enterprises of Ukraine because of the instability of economic development conditions. The grounds for the new model are determined to establish the right balance between economic, social and environmental objectives [9].

In turn, ensuring environmental security requires timely transformation based on an environmentally balanced and scientifically based development and implementation [10].

The issue of prospects of the definition of «environmental safety», the identification of its role and the need to ensure through the application of management decisions as an element of the ecoculture has been studied quite thoroughly [11, 12], but this approach is not complex and requires a change in the context of responsibility for the ecosystem.

Somebody apply comparative analysis and study the effectiveness of various classification methods (pattern recognition) based on regression models, in particular the logistic regression method and its modifications. A new method for constructing a decision function is proposed, based on the maximization of the area under the error curve in the class of decision functions linear in the space of variables obtained by a special transformation [13], but the application of this method for forecasting the ecological and economic aspects has not been sufficiently investigated.

Despite a significant number of theoretical and practical studies on environmental sustainability, the question of determining the nature of the dependence of environmental sustainability on certain factors based on the use of econometric methods remains insufficiently studied.

5. Methods of research

The following are used in research:
- matrix equations of the interbranch balance sheet model;
- least square method;
- power regression in the compilation of search forecasts.

6. Research results

The current state of the environment [14–16] indicates that emissions into the atmospheric air are directly related to the production process. When constructing a regression model, it is advisable to consider not the country's GDP as a factor of influence on the amount of pollution, namely the aggregate output in comparable prices. In this case, let's obtain a more adequate model. The functional interrelation between the elements of final demand and the total output is specified by the matrix equation of the interbranch balance model:

$$X = AX + F \rightarrow X = (I - A)^{-1} F, \quad (1)$$

where X – vector-column of the cumulative output of each industry; F – vector-column of final demand; A – square matrix of coefficients of direct costs, taking into account interbranch relations; I – the identity matrix.

The dimension of each matrix from equation (1) is equal to the number of aggregated branches. Factors of direct costs A are calculated on the basis of input statistics [15] on national accounts of the reporting year and can be used in further calculations. As a result of the application of the above model, let's obtain the following result, shown in Fig. 1.

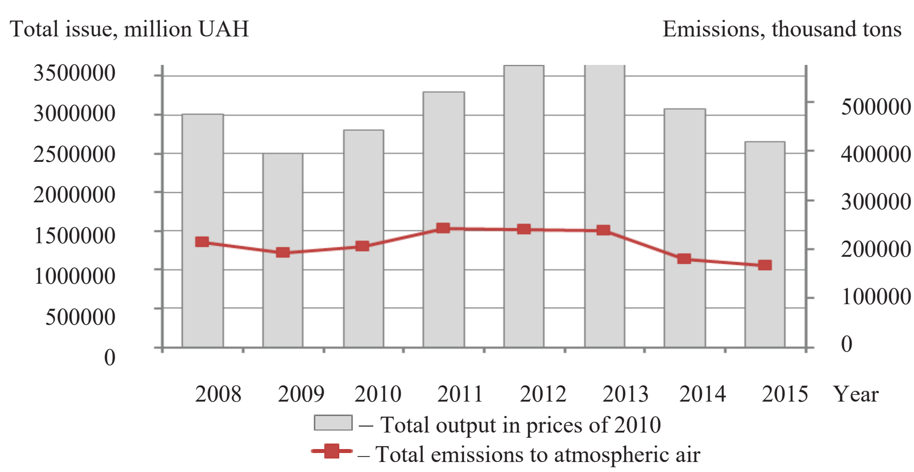

Fig. 1. Comparative dynamics of total output and volumes of atmospheric emissions for 2008–2015

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The corresponding correlation coefficient between the factor and the resultant indicators is equal $K_{cor} = 0.7950$, which indicates a high direct relationship between them.

The least squares method is used to construct the regression dependence. Moreover, both linear and power-law forms of dependencies are investigated:

1. The linear dependence of emissions in the atmospheric air (P_{atm}) from the total output (TO) in the prices of the base 2010 looks like:

$$P_{atm} = 45418.3521 + 0.053298 \cdot TO. \quad (2)$$

The adequacy of the obtained dependence is verified with the help of the Fisher criterion. The calculated value $F_{calc}=10.3048$ and exceeds the table $F_{table}(0.95; 1; 6)=5.9874$. This means that with a confidence of 95 % the regression dependence is obtained corresponds to the input statistical data [15] and can be used for scenario modeling of the dependence of emissions in atmospheric air on the volume of aggregate output.

2. The degree of dependence of emissions on aggregate output in basic 2010 prices is recorded as:

$$P_{atm} = 1.853444 \cdot TO^{0.778687}. \quad (3)$$

The verification of the adequacy of the model according to the Fisher index also indicated its acceptability with a confidence of 95 %: $F_{calc}=8.9963 > F_{table}=5.9874$. Thus, both dependencies can be used to calculate the amount of emissions to atmospheric air. Moreover, at the time interval 2008–2015 they give almost identical results.

In the compilation of search forecasts, a power-law regression (3) should be used, since it has a decreasing marginal return of the TO factor, while linear regression is characterized by a constant value. The marginal return shows how much the amount of emissions will change if the cumulative output increases by 1. Therefore, the path to economic growth can only be by increasing the share of intensive production factors.

Fig. 2 shows a comparison of the input data [15] and the calculated values of emission volumes obtained on the basis of power regression.

Thus, in this research, a functional relationship is established between the gross domestic product and the emissions of pollutants into the ambient air. The resulting regression can be used in the compilation of macroeconomic search forecasts.

The constructed regression models come out of the annual aggregate output of the Ukrainian economy, which allows to estimate the general trends in the volume of atmospheric emissions, provided that the industry structure will not change over time. In the short term, this restriction can not be taken into account, since the inertia of economic processes substantially negates the effect of this factor. However, in the medium term, this condition is no longer fulfilled. Thus, as a result of calculation of statistical data [15], input statistics on the dynamics of the sectoral structure of the output during 2008–2015 are given. On the basis of these data, an estimate of the magnitude of the structural shifts with the help of the quadratic coefficient that took place since 2008 by 2015 is carried out (Table 1).

Then the quadratic coefficient takes the values:

$$\sigma_d = \sqrt{\frac{\sum (d_{j,1} - d_{j,0})^2}{n}} = \sqrt{\frac{0.887}{7}} = 3.56\ (\%).$$

The corresponding methodology for constructing a model of the effect of economic growth on the environment state is shown in Fig. 3.

As can be seen from column 4 of Table 1, the largest changes in the structure of industrial production occurred due to agriculture (+5.4 %), processing industry (–6.9 %) and other economic activities (2.9 %). The average change in the structure of the output of each industry, according to the results of calculations, is 3.56 %. Proceeding from the fact that each industry in the process of social production has a direct impact on the state of the environment, a promising one appears (3).

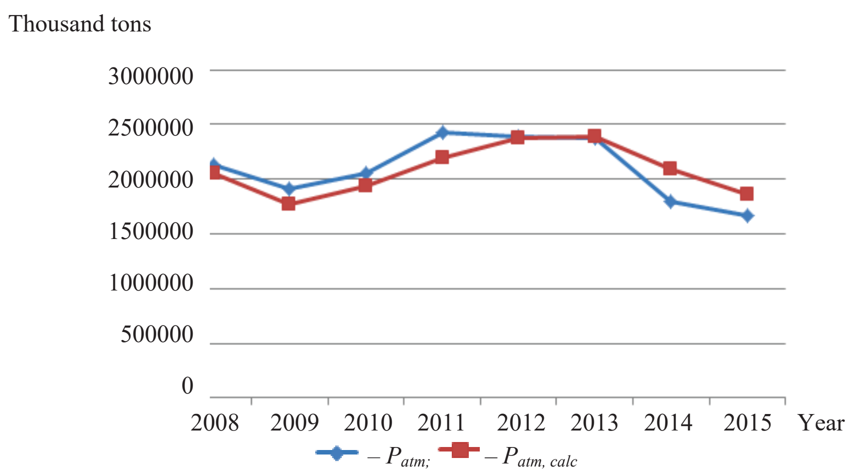

Fig. 2. Input data and calculated values of atmospheric emissions for 2008–2015

Table 1

Structural shifts in the total output of products by sectors of the economy of Ukraine according to 2008–2015

Industry	2008 $d_{j,0}$	2015 $d_{j,1}$	Structural shifts $\Delta d_j = d_{j,1} - d_{j,0}$	$(d_{j,1} - d_{j,0})^2$
Agriculture, forestry and fisheries (X_1)	7.5 %	12.9 %	5.4 %	0.290 %
Extractive industry (X_2)	4.6 %	4.7 %	0.1 %	0.000 %
Processing industry (X_3)	42.9 %	36.0 %	–6.9 %	0.476 %
Supply and distribution of electricity, gas and water (X_4)	3.4 %	4.3 %	0.8 %	0.007 %
Construction (X_5)	5.1 %	4.0 %	–1.2 %	0.013 %
Transport, storage facilities (X_6)	7.4 %	6.2 %	–1.2 %	0.015 %
Other activities (X_7)	29.1 %	32.0 %	2.9 %	0.086 %
Together	100.0 %	100.0 %	0.0 %	0.887 %

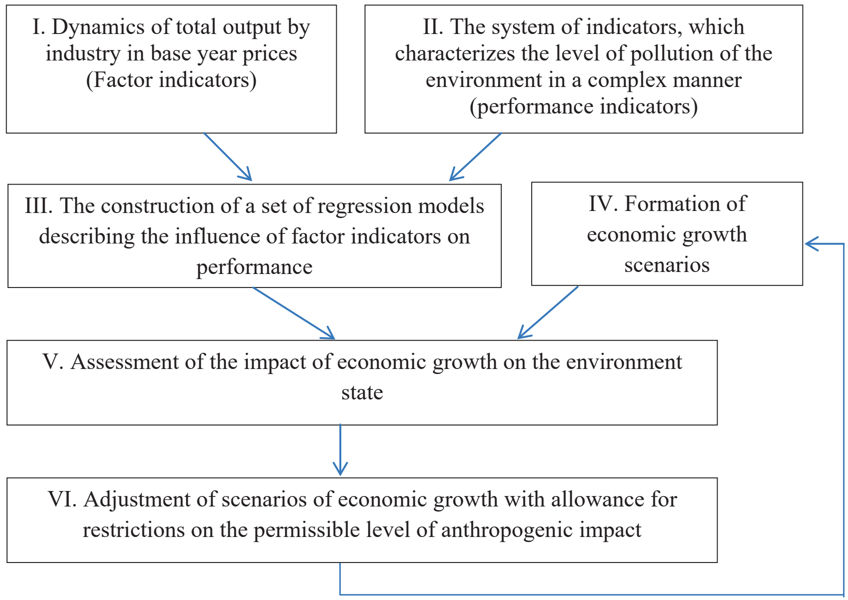

Fig. 3. Methodology for constructing a model of the impact of economic growth on the environment state

Factor indicators of the first block are determined by the dynamics of aggregate output in the context of industries in base year prices. Aggregate output by industry in Ukraine in the prices of each year, which is calculated on the basis of data on intermediate consumption and the volume of gross domestic product to determine the factors that affect the change in the indicator. Preliminary analysis indicates that for the construction of regression models, input statistical data on the dynamics of aggregate output, first of all, it is necessary to bring to a comparable type, for this purpose, the target value is calculated in the prices of the basis 2010. To designate the factor indices, let's use the ones introduced in formula (1) symbols for variable *X*, where the list of the most industries is given as the performance indicators of the second block for the construction of regression models, the indicator system is used. This complex characterizes the level of environmental pollution. They include the following indicators with the appropriate symbols:

1. Atmospheric emissions:
– volume of emissions of pollutants (AP_{pol});
– volume of carbon dioxide emissions (AP_{co2}).
2. Water resources:
– abstraction of water from natural water bodies (PN_{abst});
– volume of discharged polluted water into natural water bodies (PN_{ch}).
3. Wastes:
– volume of waste generation (W_g);
– volume of formation of wastes of I–III hazard classes (W_{haz});
– total amount of accumulated waste at the point of disposal (W_{tot});
– total volume of accumulated waste of I-III hazard classes in the places of their disposal ($W_{tot,haz}$).
4. Fertilizers: area on which pesticides were applied (F_s).
5. Forest resources:
– volumes of harvesting liquid wood (F_t);
– harvest area (F_h).

The third stage of the methodology is the construction of a set of regression models describing the impact of factorial indicators on performance indicators. To construct these dependencies, let's carry out the following:

– correlation analysis to determine the existence of a direct or inverse relationship between each resultant and a set of factor indicators and checking the significance of the calculated correlation coefficients by the Student's criterion;
– pair coefficients of correlation between factor indices are determined to justify the expediency of including a particular factor in the corresponding regression model;
– selection of many factors that significantly affect each effective indicator and carry out their verification for homogeneity by means of a quadratic coefficient of variation;
– multiple linear and power regressions are constructed between each resultant and selected set of factor indicators in order to obtain models that most reliably describe input statistical data. The models are checked for adequacy using the Fisher test.

Thus, at the output of the third block let's have a lot of regression dependencies between the industry volumes of aggregate production and the corresponding negative impact on the environment.

The fourth stage of the methodology to substantiate scenarios of economic growth suggests several possible options:

– interpolation of existing trends in the dynamics of the gross domestic product of each region for the planning period;
– implementation of the search forecast, that is, justification of the desired volume of the gross domestic product of each industry on the basis of interstate comparisons of GDP per capita.

7. SWOT analysis of research results

Strengths. Based on the obtained values of the planned volume of GDP for each industry, it is possible to calculate the corresponding interim costs and the cumulative output of each industry are supplied to the output of this block.

Weaknesses. The need to introduce new technologies or upgrade existing ones, which will lead to additional costs. The need to train existing personnel for large enterprises or the introduction of a new staffing unit for small businesses.

Opportunities. Further practical implementation of the developed methodology is justification of economic growth scenarios and assess their impact on the state of the environment using a system of equations. Reduction of the harmful influence of man on the environment in conditions of economic growth is possible due to the following factors:

– optimization of the structure of industrial production in order to increase the share of sectors with a lower environmental load in the country's GDP;
– more active use of existing treatment facilities and capital investments in resource-saving technologies that reduce the harmful impact of production activities on the environment.

Threats. Threats include:
– lack of incentives for owners to apply new technologies due to a reduction in the tax burden;
– lack of protection of domestic producers (there are no stable conditions for producers of products);
– absence of differentiation of pollutants.

8. Conclusions

1. On the basis of the analysis, let's sum up that at the present stage the question arises of uniting the efforts of the world community to preserve the natural environment, which state of the chain reaction is affected by the socio-economic processes taking place in the world. The indicator of the state of the environment is the achievement of a certain level of environmental sustainability, which is the basis of environmental safety in conditions of sustainable development. That is, environmental safety becomes the main priority benchmark and the criterion of the effectiveness of all branches of human activity, and is recognized as an important value of life activity. As a research result it is shown that the processing industry ranks first in terms of the volume of pollutants in the environment, despite a decrease in comparison with 2008 from 2015. In 42.9 % to 36.0 %.

2. As a research result, it is proved that today Ukraine, by the level of emissions to the environment, is ten times less developed than developed countries, thus it should pay attention to the increase in the share of intensive factors of production. As a result of studying the factors of influence on the environment state, it is established that this state characterizes the correlation coefficient of 0.795.

3. The regression model is constructed as a factor of influence on the pollution volumes and a functional relationship between the value of the gross domestic product and the emissions of pollutants into the atmospheric air is established. The resulting regression can be used in the compilation of macroeconomic search forecasts.

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