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## Article

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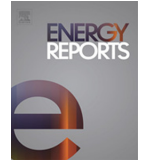
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# Influence of economic factors on the environment in countries with different levels of development

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## Abstract

The pattern of development of the economies of Europe and the world in recent decades is a focus on sustainable development. In accordance with the declaration of the United Nations Conference of 1992, sustainable development is defined as «equitable meeting the needs of present and future generations in the areas of development and the environment» and is established as one of the goals of government policy in many countries of the world. The concept of sustainable development solves the problem of choosing between achieving a high rate of economic growth and maintaining a clean environment. The purpose is to study and quantify the impact of economic factors on the state of the environment in countries with different levels of development. The study revealed existing patterns and built new mathematical models that can be used in strategic planning, allow predicting the possible environmental consequences of economic growth in Europe and the world. The use of the proposed models allows not only to assess the impact of economic growth on the environment in retrospect, but also to highlight the most significant factors contributing to the reduction of environmental pressure in the future.

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**Keywords:** CO2 emissions; Environmental policy; Demography; Econometric methods; Economic growth; Environment; European Union; Sustainable development

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## 1. Introduction

Sustainability of development is supported by the fact that economic growth contributes to the improvement of production technologies in the direction of environmental friendliness, thereby ensuring sustainable development.

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Features of the economic development of European countries lead to significantly different environmental consequences that must be considered when making strategic decisions. Sustainable development involves ensuring environmental and economic balance, resolving contradictions between economic activities and the natural environment. Therefore, the problems of developing tools for assessing the impact of the economy on the environment in countries with different levels of development are becoming increasingly important, this is studied in the article by Eder et al. (2017a) [1].

The purpose of this study is to study and quantify the impact of economic factors on the state of the environment in countries with different levels of development.

In accordance with the goal, we formulated the following tasks, which determined the structure of the work as a whole: (1) a review of existing approaches to quantify the contribution of economic and technological factors to the dynamics of greenhouse gas emissions; (2) Analysis of trends in economic growth, taking into account the interaction with the environment; (3) using factor analysis, determining the parameters affecting the dynamics and interrelation of the process of ecological and economic development.

The authors used mathematical modeling methods, assessed the impact of various economic, technological, resource and demographic factors on the dynamics of environmental indicators. For the calculations, the IPAT model was used, which allows to take into account the impact of structural changes in the economy, production modernization and environmental investments on environmental pollution indicators. As factors in the model, the population size, gross domestic product, industrial production per capita, technological level, as well as the share of industry and agriculture in GDP, the share of exports and imports.

Modern researchers pay special attention to the relationship between economic growth and air pollution indicators at the level of individual sectors of the economy. So in a study by Marin and Mazzanti (2013), panel data from 1990–2007 are used, confirming the relationship [2]. The results confirm various trends: from achieving the effect of absolute decoupling to a directly proportional relationship between the volume of production and emissions to the atmosphere. The development of the service sector, as a rule, is accompanied by a more pronounced decrease in the burden on the environment than the growth in manufacturing industry. The work highlights the most problematic sectors of the economy. A similar example is observed in the next article by Darkoh (1996), where global trade trends, commodity dependence on commodities and the relationship between trade, environment and development are considered [3]. The dependence of the deterioration on commodities is shown in the examples of Papua New Guinea, Botswana and Somalia. Most of the works as in article by Sharf et al. (2014a), (2014b) are devoted to research at the level of one state and are associated only with certain types of environmental pollution [4,5], so Cramer (1998) of article found correlation dependence only types of pollutants [6].

In the work of York et al. (2003) obtained the results of studies of panel data covering 86 countries of the world, confirm the population growth leads to an increase in the share of emissions [7]. The authors also found that the impact of population size on CO<sub>2</sub> emissions increases with increasing levels of urbanization and a decrease in the average household size in developed and developing countries.

Despite numerous studies in this area, most of the scientific works do not allow to accurately identifying those factors that have a significant impact on reducing the negative impact on the environment and are subject to control by government authorities or companies, this is considered in the works of such authors as Carayannis et al. (2017), Cherepovitsyn et al. (2018), Eder et al. (2017b), Dukelow et al. (2017) [8–11]. Another study by Eder et al. (2017c) also addresses this issue and addresses it in a project funded by the European Union Framework Program, which allows for an analysis of the interaction between the three main processes and discourses of globalization, development and sustainability [12].

The authors consider an approach that is based on the pollution function, using the IPAT model. OECD countries were considered, including: USA, Canada, Mexico, Austria, Belgium, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Israel, Australia, New Zealand, and South Korea. The authors determine the advantages of the constructed model and the prospects for their application for analyzing and predicting the impact of economic development on the environment. The choice of countries is justified by the fact that European countries are advanced in terms of legal regulation and in support of the environment, a developed legislative base that contributes to the improvement of environmental development. At the same time, there is a differentiation in the level of economic development, therefore, it is scientifically interesting to study the experience of such countries.

## 2. Methodology

This study uses the model IPAT, which is discussed in detail in the works of the authors Commoner (1972) and Erlich (1971) [13,14]. This is an identity that defines the three factors of anthropogenic environmental impact. The impact that a person has on the environment is expressed quantitatively as the product of population, wealth and technology. This allows you to structure an analysis of the driving forces underlying the dynamics of polluting emissions.

$$I = P \times A \times T \quad (1)$$

Decomposition of the dynamics of emissions into the influence of predetermined factors is based on the analytical concept of indices and is an extension of the index method of factor analysis applied to the environment economy. The basis for constructing an aggregated index is the IPAT environmental model, which expresses the human impact on the environment (I, impact) as a product of the population (P, population), welfare (A, affluence) and technology (T, technology), which for the case of carbon dioxide emissions from fuel combustion is represented as Kaya (1990) identity [15]:

In 1990, J. Kaya expanded the IPAT model in the case of energy consumption that entails emissions of carbon dioxide into the atmosphere. In this model, the factors of the amount of carbon dioxide emissions are: population, gross domestic product per capita, energy intensity of the gross domestic product and the amount of carbon dioxide emissions.

$$CO_2 = POP \frac{GDP}{POP} \frac{EC}{GDP} \frac{CO_2}{EC} = POP \times G \times E \times CI \quad (2)$$

where  $CO_2$  — carbon dioxide emissions from fuel combustion,  $POP$  — population,  $GDP$  — Gross domestic product,  $EC$  — total energy consumption,  $G$  — GDP per capita,  $E$  — energy intensity of GDP (energy use technology),  $CI$  — the intensity of energy produced (energy production technology).

The combination of all factors determines the dynamics of carbon dioxide emissions from fuel combustion. Our goal is to evaluate the quantitative contribution to the observed changes in carbon dioxide emissions using the textured model.

The authors decided to use the total decomposition method, since for volume indicators, such as carbon dioxide emissions, this is natural.

Decomposing observed changes in carbon dioxide emissions  $\Delta CO_2$  using the model gives us the contribution of the following factors: the effect of population  $\Delta C$  (POP); income effect  $\Delta C$  (GDP); the effect of changing the energy intensity of GDP  $\Delta C$  (enint); the effect of changing the share of energy, the production of which is not related to the burning of fossil fuels, in the total energy consumption  $\Delta C$  (rew); the effect of changing the emission factor of the  $i$ th type of fossil fuel  $\Delta C$  (ems).

$$\begin{aligned} \Delta CO_2 &= CO_2(t) - CO_2(t-1) \\ &= \Delta C(POP) + \Delta C(GDP) + \Delta C(enint) + \Delta C(rew) + \Delta C(FF) + \Delta C(ems), \end{aligned} \quad (3)$$

To estimate each effect, the method of the average logarithm of the Divisia index LMDI-1 is used, which are expressed as follows using the example of a change in carbon dioxide emissions with an increase in the country's population, assuming that all other factors remain unchanged, etc. with other factors:

$$\Delta C(POP) = \sum_{i=1}^3 \frac{CO_2(t) - CO_2(t-1)}{\ln(CO_2(t)) - \ln(CO_2(t-1))} \ln\left(\frac{POP_t}{POP_0}\right) \quad (4)$$

where  $CO_2$  — the total carbon dioxide emissions,  $POP$  — the population.

The effect of each factor will be a hypothetical change in carbon dioxide emissions from fuel combustion, which would occur as a result of a change in this factor, provided all other factors are constant.

## 3. Results and discussion

The results of the total decomposition of carbon dioxide emissions from fuel combustion for the periods 1990–1995, 1996–2000, 2001–2005, 2006–2010, 2011–2014, 2015–2016 in absolute and relative terms (See Table 1).

**Table 1.** Changes in carbon dioxide emissions from fuel combustion and the effects of population, income, GDP energy intensity, share of non-fossil energy and fossil fuel emission factors over periods.

Years	$\Delta\text{CO}_2$	$\Delta\text{C (POP)}$	$\Delta\text{C (GDP)}$	$\Delta\text{C (enint)}$	$\Delta\text{C (rew)}$	$\Delta\text{C (FF)}$	$\Delta\text{C (ems)}$
In relative terms, [%]							
1990–1995	100	0.9	4.0	−3.3	−0.6	0.5	−0.4
1996–2000	100	0.5	3.6	−3.3	−0.6	0.2	0.0
2001–2005	100	5.3	28.5	−27.8	−1.8	1.0	−4.2
2006–2010	100	−0.3	−1.3	1.8	0.2	0.4	0.3
2011–2014	100	−0.7	−3.3	4.3	−0.4	0.5	0.5
2015–2016	100	0.9	2.9	−2.4	−3.1	3.4	−1.1
In absolute terms, [million tons]							
1990–1995	242	210	958	−799	−154	133	−106
1996–2000	344	188	1227	−985	−156	73	−2
2001–2005	36	191	1035	−1010	−65	37	−152
2006–2010	−556	187	745	−989	−116	−231	−152
2011–2014	−224	148	747	−964	81	−121	−115
2015–2016	34	30	101	−84	−94	118	−37

The decomposition of the observed changes in the amount of carbon dioxide emissions from fuel combustion  $\Delta\text{CO}_2$  over a certain period of time contributes to the following factors:

The population effect is  $\Delta\text{C (POP)}$ , which is a change in carbon emissions due to a change in the number of inhabitants in a country;

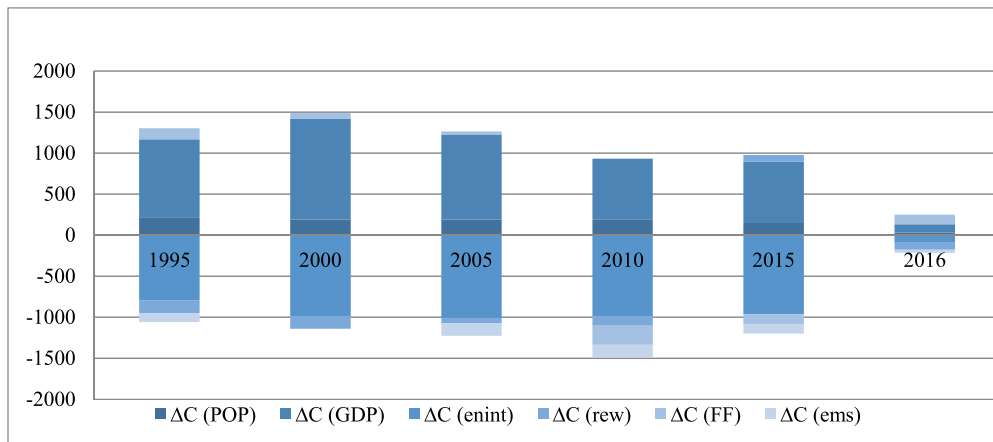
The income effect is  $\Delta\text{C (GDP)}$ , which measures the change in carbon dioxide due to a change in per capita GDP (as an indicator of change in welfare);

The effect of changing energy intensity of a GDP is  $\Delta\text{C (enint)}$ , which measures the change in the intensity of energy use depending on the choice of production technology (if an increase in production exceeds the increase in energy costs, this effect leads to a decrease in emissions);

The effect of changing the energy produced, which measures the content of carbon dioxide emitted into the air (a lower value of carbon dioxide emissions in the production of one energy unit is an indicator of the use of cleaner energy production technologies).

Each effect is measured in the proposal of the invariance of all other factors.

The effects of income and energy intensity were the main determinants of carbon dioxide emissions in OECD countries. The effects associated with energy production technology have contributed less to this dynamic (See Fig. 1).



**Fig. 1.** Changes in carbon dioxide emissions from various factors in OECD countries, million tons. Source: Calculated by the author based on data from BP Statistical Review of World Energy, June 2018.

#### 4. Conclusion

Economic growth is crucial in improving production technologies and increasing the demand for the environment by the population, thereby contributing to the goals of sustainable development.

The authors have developed a set of statistical methods for analyzing the dynamics and interrelations of economic and environmental development in OECD countries in the period 1990–2016.

The study revealed existing patterns and built new mathematical models, including a decomposition analysis of the modified Kaya set. This can be used in strategic planning, the models allow to predict the possible environmental consequences of economic growth in Europe and the world.

The use of the proposed models allows not only to assess the impact of economic growth on the environment in retrospect, but also to highlight the most significant factors contributing to the reduction of environmental pressure in the future.

The essence of the statistical methodology, revealing the quantitative patterns of the structure, dynamics and interrelations of the unique experience of ecological and economic development of OECD countries, passing through different stages of transition to a developed industrial and post-industrial economy, determines the relevance of this study.

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