Model of Analysis of Ecological-Economic Processes

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Abstract. This article presents a model for assessing the impact of environmental factors on economic performance and optimizing industrial production taking into account environmental costs. The modeling showed the influence of production and environmental parameters on the sustainable development of the economy and revealed the dynamic dependence of the volume of industrial production on time. The model can be used to analyze and predict the effectiveness of environmental measures, as well as to make smart decisions in the field of sustainable development and environmental protection. The developed program shows how the volumes of industrial production and pollutants emitted into the atmosphere change in various areas. Model parameters include initial values of industrial production, volumes of labor resources, capital utilization rates, cleanup costs, depreciation, disposal of funds, minimum values of production and environmental funds, and coefficients of the impact of pollution on the economy. The simulation calculates production volumes, pollution treatment, environmental damage, and environmental income, and then updates industrial production volumes considering depreciation, accumulation, and diffusion. The results demonstrate the dynamics of changes in the production of industrial products and make it possible to determine the volumes of industrial production and pollutants emitted into the atmosphere by region. Graphical results presentations illustrate temporal changes in industrial production and air pollutant emissions by region, facilitating the understanding and management of environmental and economic interactions.

Key Words: Environmental-economic model; Industrial products; Pollutants.

1 Introduction

In Uzbekistan, nature conservation is of critical importance. All areas of human activity are highly dependent on natural resources, and their use is a vital component of further socio-economic development. The environmental situation in Uzbekistan and throughout the world requires an immediate rethinking of humanity, peoples and each individual person. The disappearance of the Aral Sea is one example of a global environmental crisis. Desertification

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is another serious environmental problem facing humanity at the beginning of the 21st century. This is especially important for arid regions [1, 2].

Due to the restoration of natural resources and global warming, the relationship between economic development and environmental conservation is becoming increasingly relevant. Economic progress based on unlimited resource consumption and high levels of pollution often leads to harmful consequences for both ecosystems and human health. Such situations require models that take into account the relationship between economic development and the environment [3-5].

Dynamic eco-economic models are used to explore these relationships and predict how different economic policies and environmental interventions will harm each other. They allow making informed decisions in the field of environmental protection and analyze the influence of various factors on the sustainability of economic development. This study presents a dynamic eco-economic model based on diffusion equations. This model allows us to show how the production of industrial products and pollutants emitted into the atmosphere are distributed across regions in time and space [6-9]. The model takes into account the relationship between economic and environmental processes. It can be used to assess the effectiveness of environmental measures and forecast economic development in various situations [10-12].

The purpose of this work is to create and use a dynamic ecological-economic model based on diffusion equations in order to study the interaction between economic processes in Uzbekistan and the state of the environment. The model allows us to assess how changes in the production and use of resources in various sectors of the economy affect the level of pollution and the state of the environment. This will allow us to find effective methods for managing natural resources that minimize negative impacts on the environment while reducing economic costs. The main scientific achievement of this work is the creation of a dynamic ecological-economic model based on diffusion equations. This model takes into account the relationship between economic and environmental processes, taking into account changes occurring over time and space. It shows how changes in the environment affect production processes and vice versa. This allows one to analyze how economic activity affects the state of natural resources and vice versa. The model that has been developed can be used to study different approaches to natural resource management, assess how effective conservation measures are, and make informed decisions [13, 14].

The model allows assessing how changes in the production and use of resources in various sectors of the economy affect the level of pollution and the state of the environment. The study identifies effective methods of natural resource management that minimize negative impacts on the environment. The model can be used to predict the consequences of economic decisions on the state of ecosystems and their sustainability in the long term, which makes it possible to prevent adverse consequences [15, 16].

The model assesses how changes in the production and use of resources in various sectors of the economy affect the level of pollution and the state of the environment. The study pinpoints effective methods of natural resource management that minimize negative impacts on the environment. Using the model, it is possible to evaluate the effectiveness of various environmental measures and programs, such as the introduction of environmentally friendly technologies or the creation of nature reserves and protected areas. The model allows for a comparative analysis of the environmental and economic situation in different regions and to identify features of sustainable development depending on local conditions and economic characteristics [17, 18].

Such results can be useful both for the formation of state environmental policy and for the development of sustainable development strategies at the local and regional levels. When modeling economic and environmental assets, these industries can be considered as different sectors in which the production and use of resources occurs. The final values of the volumes of industrial production and pollutants emitted into the atmosphere by region, which we obtained in the model, reflect the dynamics of changes throughout the entire modeling time [19-22].

2 Methods and Models

Consider a dynamic macroeconomic ecological-economic model that takes into account the interaction of economic and environmental processes. The model uses vectors and matrices to describe various aspects of production and environmental processes. To take into account the dynamic aspects of the accumulation of the final product and the costs of pollution with a non-rigid specification of the volumes of industrial products and pollutants emitted into the atmosphere.

Formulate the initial equations and limitations of the dynamic ecological-economic model:

$$\Phi_i^1(K_i, L_i X_i) = K_i^{\alpha_1} L_i^{\alpha_2} X_i^{\alpha_3},$$

$$\Phi_i^2(R_i, C_i) = R_i^{\beta_1} C_i^{\beta_2},$$

$$E_i(t) = \alpha\Phi_i^1(K_i(t-1), L_i, X_i) - \beta\Phi_i^2(R_i(t-1), C_i),$$

$$Y_i(t) = \Phi_i^1(K_i(t-1), L_i, X_i) - E_i(t),$$

$$K_i(t) = K_i(t-1)(1-\delta_i) + D_{K_i}(K_{i+1}(t-1) + K_{i-1}(t-1) - 2K_i(t-1)),$$

$$R_i(t) = R_i(t-1)(1-\gamma_i) + D_{R_i}(R_{i+1}(t-1) + R_{i-1}(t-1) - 2R_i(t-1)).$$

where the volume of industrial output in the region i at the time t is equal to $K_i(t)$.

The volume of pollutants emitted into the atmosphere in the region i at time t is equal to $R_i(t)$. L_i represents the amount of labor in the region i. The amount of resources in a region is called X_i. C_i is the cost of environmental measures in the region i. The depreciation coefficient of production assets in the region i is called δ_i. Disposal rate of environmental funds in the region i. The α coefficient shows the impact of pollution on the economy. The pollution reduction coefficient D_{K_i} is the coefficient of distribution of production resources in the region i. D_{R_i} is the coefficient of distribution of environmental resources in the industry.

Dynamic models take into account the dynamics of expansion of gross output, which distinguishes them from static models. The presented dynamic model allows us to take into account less complex patterns of final product accumulation and pollution. This model can be used to analyze and optimize macro-level components of environmental and economic processes. The application of such models in the field of natural resource management and environmental protection contributes to sustainable economic development and improvement of the quality of life of the population.

3 Results and Discussion

The developed program takes into account changes in the volume of industrial production and pollutants emitted into the atmosphere in 13 different regions. The parameters used in the program include the initial values of the volume of industrial production and pollutants emitted into the atmosphere, retirement, and depreciation coefficients of assets, as well as pollution impact coefficients of the Republic of Uzbekistan. Modeling occurs diffusely and is carried out over a certain period. The simulation results are presented in graphs that show

how the volumes of industrial production and pollutants emitted into the atmosphere change in accordance with the requirements. Based on the data obtained, it is possible to draw conclusions about how different regions affect the state of the environment as a whole, as well as assess the effectiveness of environmental protection measures.

The program that has been developed will allow us to assess the impact of environmental factors on economic indicators and determine the most effective methods for managing the production of industrial products, taking into account environmental costs. Over the course of ten years, this code predicts the volume of industrial production and pollutants emitted into the atmosphere for thirteen regions. The initial values of industrial production, pollutants emitted into the atmosphere, the volume of labor resources, depreciation and disposal rates, minimum values of products and environmental funds, as well as coefficients of the impact of pollution on the economy are the main parameters of the model. How the production of industrial products and pollutants released into the atmosphere changes over time depends on the functions of production and processing of pollution. Production volume, pollution treatment volume, environmental damage and environmental income are determined at each time step. The funds are then renewed through depreciation, accumulation and distribution. The modeling results show how industrial production and pollutants emitted into the atmosphere change over time in each region. The final values are output and graphs are created to show how their values change. Initially, model parameters such as the number of industries (n) and simulation time (T) are determined. Then the initial values for each region are set. These initial values include initial industrial production (K_initial), initial emissions of pollutants (R_initial), initial labor (L), capital utilization rates (X), cleanup costs (C), disposal rates (gamma), minimum values of production (Y_min) and minimum values of the volume of pollutants emitted into the atmosphere (P_min). Next, the coefficients of the impact of pollution on the economy and diffusion parameters for production and environmental funds are established. Then the specifics of the production and processing of contaminants are discussed.

The volume of industrial production and pollutants released into the atmosphere changes over time. The production volume (F), pollution treatment volume (G), environmental damage (E) and environmental income (Y_eco) are determined at each time step. Fund levels are then updated to reflect depreciation, accumulation and distribution. Consequently, for each region the volumes of industrial production and pollutants emitted into the atmosphere are determined. In addition, graphs are created showing how these values change over time (Tables 1 and 2, Fig. 1).

Table 1 provides data on the total volume of industrial production for various regions of the Republic of Uzbekistan, measured in trillions of soums. It presents values for 13 regions, which allows for a comparative analysis of the level of industrial development in these regions. The data show significant variation in output, reflecting the heterogeneity of economic activity across the country.

Table 1. Volume of industrial production by region (trillion sum).

Region 1	Republic of Karakalpakstan	22.455
Region 2	Andijan region	64.916
Region 3	Bukhara region	33.109
Region 4	Jizzakh region	20.944
Region 5	Kashkadarya region	32.760
Region 6	Navoi region	88.361
Region 7	Namangan region	27.846
Region 8	Samarkand region	29.346
Region 9	Surkhandarya region	10.690
Region 10	Syrdarya region	21.473
Region 11	Tashkent region	92.551

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Region 12	Fergana region	39.087
Region 13	Khorezm region	22.174

Table 2 shows the volumes of pollutant emissions into the atmosphere in various regions of the Republic of Uzbekistan, measured in thousands of tons. Analysis of the table helps to identify regions with the highest and lowest environmental load, which is important for developing measures to reduce the negative impact on the environment.

Table 2. Pollutants released into the atmosphere (thousand tons).

Region 1	Republic of Karakalpakstan	19.572
Region 2	Andijan region	18.675
Region 3	Bukhara region	33.178
Region 4	Jizzakh region	34.352
Region 5	Kashkadarya region	101.865
Region 6	Navoi region	43.976
Region 7	Namangan region	12.324
Region 8	Samarkand region	33.287
Region 9	Surkhandarya region	13.948
Region 10	Syrdarya region	75.541
Region 11	Tashkent region	375.183
Region 12	Fergana region	75.715
Region 13	Khorezm region	10.615

The dynamics are shown in Fig. 1.

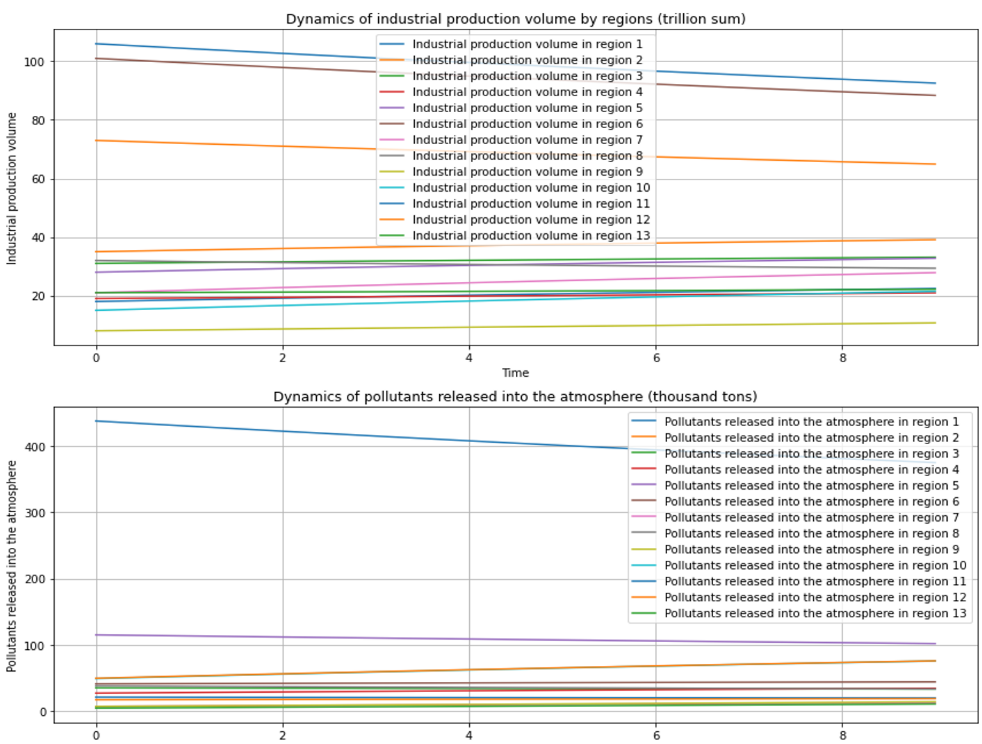

Fig. 1. Dynamics of the volume of industrial production and pollutants emitted into the atmosphere by region (Data taken from the open source stat.uz).

These graphs show how each region's industrial output and air pollutant emissions changed over the simulated period, allowing them to evaluate the effectiveness of different management practices and strategies. Regions with high initial values of industrial production volumes of pollutants emitted into the atmosphere (for example, region 2 and region 11) continue to remain at high levels, which may indicate that these regions are stable and sustainable. A significant increase in air pollutants emitted in some regions (for example, region 11) indicates deterioration in environmental protection. This analysis helps draw conclusions about the state of the region and identify areas for investment and improvement.

Regions 3, 4, 5, 7, 10, and 12 showed steady growth or little change, indicating good conditions and good management. Regions 7, 9, 10, 12, 13 showed a significant deterioration in air pollutants emitted, indicating that in these industries environmental measures are of paramount importance. Regions 2, 6, and 11 showed a significant decrease in production assets; therefore, it is necessary to analyze and take measures to improve the situation. Regions 5 and 11 showed significant reductions in pollutants released into the atmosphere, indicating the need to reconsider environmental approaches. From the results obtained, we can conclude that it is necessary to conduct a thorough analysis of the reasons for the decrease in funding in problematic regions, and develop strategies to optimize them. Strengthen environmental measures in industries where the levels of pollutants released into the atmosphere have increased significantly. It is necessary to support and develop regions that demonstrate stable growth and improvement to achieve sustainable development. These tips will improve overall industrial output and reduce pollutants released into the atmosphere, promoting sustainable development and minimizing negative impacts.

The results confirmed the importance of the interaction between economic activity and the environment around us. The presented model suggests that the impact of production and pollution on macroeconomics is a significant contribution to economic and environmental science. The research can help inform development risk reduction and environmental protection policies. Understanding how economic and environmental processes relate to each other will help guide conservation decisions. The development of more complex models using more accurate data and parameters, as well as the study of additional variables that influence variability in industrial production and air pollutant emissions, may be the subject of further research. The study thus provides valuable scientific and practical insights. These data can be used to develop effective methods to increase development and protect the environment.

4 Conclusion

The creation and analysis of macromodels of environmental and economic processes allow us to assess the impact of environmental principles on the development of the national economy and develop strategies to minimize these principles. The presented model allows us to better understand the structure of gross output and pollution costs at the macro level, the interactions between regional production volumes, chemical restrictions, and environmental costs. By using such models in the field of natural resource management and environmental protection, it is possible to improve the quality of life of the population and ensure sustainable economic development, while simultaneously reducing the negative impact on the environment. The results confirmed the importance of the interaction between economic activity and the environment. The presented model suggests that the impact of production and pollution on macroeconomics is a significant contribution to economic and environmental science. The research can help inform development risk reduction and environmental protection policies. Understanding how economic and environmental processes relate to each other will help guide conservation decisions. The development of more complex models using more accurate data and parameters, as well as the study of additional variables that influence the variability of production and environmental funds, may be the subject of further research. The study, thus, provides valuable scientific and practical insights. These data can be used to develop effective methods to reduce development and protect the environment.

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