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MACROECONOMIC INDICATORS AND CO₂ EMISSIONS IN THE EU REGION

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Abstract

The anthropogenic emissions of carbon dioxide into the atmosphere are one of the problems facing mankind on a global scale. Therefore, the governments of many countries are making efforts to reduce CO₂ emissions through regulatory measures. Environmental pollution from CO₂ emissions is not only an environmental problem, but also an economic one. Therefore, the authors focus on conducting a multi-econometric study of the impact of macroeconomic factors (gross domestic product, exports, imports, inflation, and unemployment) on CO₂ emissions in the EU region. Systematization, empirical comparative analysis, and econometric modeling (determining the relationships between indicators) were the research methods applied in our research. The results, which were carried out based on statistical data for the period 1970-2020 in the EU, confirmed the existence of dependence of carbon dioxide emissions on macroeconomic indicators such as gross domestic product, exports, imports, inflation, and unemployment. To know whether to reduce or maintain allowable CO₂ emissions, governments can use multivariate regression models to optimize, monitor, and forecast their macroeconomic indicators.

Keywords: greenhouse gases, carbon dioxide, gross domestic product, inflation, exports, imports, unemployment, EU.

JEL Classification: C01, E01, E24, E31, F18, O13, Q51, Q53.

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Introduction

Climate change is one of the biggest challenges modern society faces now. It relates to both developed and developing countries. It is no wonder then that one of the most topical issues of the present day is the problem of preserving the environment, which is polluted by harmful emissions into the atmosphere of various gases that create a greenhouse effect. It is necessary to ensure the application of environmental principles, maintain the environment, and reduce environmental damage (Astawa et al., 2021; Shpak et al., 2022). Therefore, companies embrace technological progress as a determinant of competitiveness but with a balance between business, ecology, and society (Florek-Paszowska, Ujwary-Gil and Godlewska-Dzioboń, 2021; Gajdzik, Grabowska and Saniuk, 2021a). The greenhouse effect destroys the ozone layer around the planet, resulting in global warming. Furthermore, it is necessary to adjust the structure of the industry in accordance with the needs for environmental protection (Li et al., 2017; Potoczek, 2021). The latest report from the IPCC Working Group notes that carbon dioxide makes the largest contribution to climate change, followed by methane, haloalkanes, and nitrous oxide (IPCC, 2007). The onset of the industrial revolution in the mid-19th century led to a violation of the balance of the carbon cycle and an increase in CO₂ concentration. Therefore, the Kyoto Protocol was signed in 1992. To date, the Protocol has been signed and ratified by 191 countries (UNFCCC, 2009), including the most industrialized countries, except the United States, which has signed but has not ratified the agreement. In addition, there is also the Paris Climate Agreement (signed in 2015), which regulates the reduction of CO₂ emissions (EU Neighbours East, 2019). However, the Paris Climate Agreement provides for countries to define their goals based on their national priorities and characteristics (temporarily occupied territories, the struggle against poverty, etc.). Thus, the country's climate goals should not limit it when it comes to achieving other Sustainable Development Goals (Androniceanu, 2019), including economic ones (UBTA, 2021). This makes the country's economic development dependent on CO₂ emissions, which require the analysis not only of environmental aspects, but also of economic ones.

Environmental pollution is certainly not only an ecological problem but also an economic one. In large cities, the sources of pollution are industry and transport. The production structure of the economy has a very large impact on CO₂ emissions (Androniceanu, 2020; Prokopenko et al., 2020). According to the EDGAR database (Crippa et al., 2020), the countries and regions with the highest carbon dioxide emissions during the period 1970-2019 arising from certain types of human activity include the European Union, the United States, Russia, China, and Japan (Crippa et al., 2020; World Bank, 2020). For this reason, the need to analyze CO₂ emissions in one of the leading regions, such as the EU, is urgent.

1. Literature Review

Pollution of the atmosphere through harmful emissions such as greenhouse gases is an issue on which much research is based (Kim and Jeong, 2018; Zheng et al., 2019; Gajdzik and Sroka, 2021; Gajdzik, Sroka and Vveinhardt, 2021b). Since environmental pollution by means of CO₂ emissions is not only the result of natural processes, but is largely due to human activity, the issue of anthropogenic impact on the level of CO₂ emissions is actively covered in scientific sources, especially as a result of the economic activity (Fosten, 2019; Shpak et al., 2021) of all entities of business activity, households, enterprises, corporations, and states.

To study the ecological and economic interaction over time, it is necessary to apply the apparatus of economic and mathematical modeling concerning the formation and study of dynamic models. This allows one to obtain the trajectories of the variables studied, in particular, distinguishing the equilibrium ones among them, which makes it possible to predict the behavior of the indicators studied. The modeling of the dynamics of harmful emissions by different researchers was mainly carried out within the following types of model: simulation models (Ahmed and Ahmed, 2018); regression models (Liu et al., 2021; Ardakani and Seyedaliakbar, 2019); taxonomic analysis (Shpak et al., 2019); dynamic simultaneous equation models (Saidi and Hammami, 2015b); and other variants.

In the opinion of the authors, the issue of performing an analysis of the economic consequences of the negative impact of environmental pollution on public health should be the most relevant, since the effectiveness of the country's economic development depends on the health of the employees. Kalenska (2012) and Kubatko (2009) carried out studies on how the state of health affects household income, finding a relationship between the deterioration of public health and a decline in household income. The impact on the environment and its degradation is closely related to the level of economic well-being of the country: the better a country is, the lower the levels of degradation. At the same time, some studies (Ali, Akter and Fogarassy, 2021; Gill, Hassan and Viswanathan, 2019) revealed regularity based on the analogy of S. Kuznets' hypothesis on the relationship between the level of income inequality and the growth there: when income per capita increases, the level of environmental degradation first increases and then, at a certain level of welfare, begins to decline. In theory, this pattern is described by a curve called the Kuznets environmental curve (Ma, Ahmad and Oei, 2021). According to this theory, a decrease in the unemployment rate in a country and an increase in personal income caused by economic growth indicate some positive effects on the environment and resource use, providing increased sensitivity to the environment and demand for environmentally friendly goods. According to Beckerman (1992), an increase in people's income creates an opportunity to prevent environmental pollution, as demand for a qualified environment increases and a qualified environment becomes a luxury to a necessity. Similarly, on a larger scale, this theory is valid not only for individuals but also for large corporations, i.e. an effective environmental policy can cooperate with the existing system of capitalist corporations, and growth can be achieved without harming the environment (Christoff, 1996).

The main macroeconomic indicator that can characterize the level of income of the country as an aggregate indicator of the income of its entities is the volume of gross output. The relationship between national product production volumes and emissions of hazardous substances into the atmosphere is obvious in scientific research. Thus, the study (Oreshnyak, 2013) found a correlation between 1) GDP growth rate per capita in purchasing power parity (PPP) and a change in carbon dioxide (CO₂) emissions; 2) a change in CO₂ emissions and a change in the shares of individual sectors of the economy. The work of scientists (Kovpak, 2017) is devoted to evaluating and analyzing the closeness of the relationship between the total amount of harmful emissions into the air of Ukraine and indicators to measure GDP: at constant prices, at current prices, and "green" GDP. In one source (Tymoshenko and Us, 2016) the dependence of the level of air pollution on the volume of gross production of the main industrial polluting enterprises of Dniprodzerzhynsk (Ukraine) is established.

At the moment, the task for most countries is economic growth with a moderate increase or decrease in emissions. Countries apply different approaches to state regulation of greenhouse

gas emissions, in particular the use of carbon taxation of industrial pollutants (Nekrasenko et al., 2015; Ivanenko and Sas, 2017), the introduction of innovative resource-saving technologies and increasing the technical support (Sharko and Andrusenko, 2017; Shkola et al., 2021), the production of renewable energy (Wąs et al., 2020), and the strengthening of economic levers at the municipal level to protect the environment of the air basin of industrial cities (Tymoshenko and Us, 2016).

In addition to GDP, the authors of scientific resources study the impact of other macroeconomic indicators on the volumes of emission of hazardous substances. In particular, as a result of statistical data research by Tymoshenko and Us (Tymoshenko and Us, 2016), it is established that there is no correlation between the volume of capital investments and the volume of emissions of hazardous substances, and an increase in current expenditure on air protection does not lead to a decrease in emissions from stationary sources of pollution. Researchers analyze the impact of economic growth, international trade, and urbanization (Iheonu et al., 2021), the development of the tourism sector (Ma et al., 2021) and the transport sector (Karyy and Podvalna, 2016), and technical and social aspects (Androniceanu and Tvaronavičienė, 2019; Pui and Othman, 2019) on CO₂ emissions.

According to a group of scientists united by the international Global Carbon Project, restrictions in place in much of the world, not least related to the business environment, during the COVID-19 pandemic led to a decrease in CO₂ emissions by 7% in 2020 compared to the previous year. In a study published on December 11, 2020, global air emissions in 2020 were estimated at 34 billion tons of greenhouse gases. The reduction in CO₂ emissions was 12% in the United States and 11% in the European Union. However, emissions were reduced by only 1.7% in China, which was able to restart its economy after the first wave of the virus at the beginning of the year (Radio Svoboda, 2020). The greatest reductions occurred in the production, housing, retail, wholesale, transport, and food sectors, which account for more than 93.7% of the total change in CO₂ (Andreoni, 2021; Prokopenko et al., 2021). According to The Guardian, in 2021 countries would again begin to invest in coal, gas, and oil to accelerate recovery from the economic crisis caused by the COVID-19 pandemic, which would increase CO₂ emissions by almost 5% (Rubryka, 2021). In other words, the COVID-19 pandemic would not give countries a good reason to postpone efforts to mitigate the effects of climate change (Kozlovskiy et al., 2021).

Scientific research sources confirm that ensuring ecological and economic balance is one of the main and most urgent problems facing the global economy. This research aims to correct flaws since many researchers focus either on the collection of statistics in terms of certain environmental and economic processes, or the development of mathematical models of environmental and economic systems and processes without taking into account the relationship of these models to statistical data, which are quite abstract and not directly related to the real economy. Furthermore, most studies are limited to a short period (1990-2012 (Saidi and Hammami, 2015a); 1990-2017 (Liu, Lin and Xu, 2021); and 1995-2016 (Khan et al., 2019)), but, in the authors' opinion, anthropogenic activity has a long-term effect on the environment. The influence of economic factors may not manifest itself immediately. Given that the World Bank has been providing statistics since 1970, this study aims to examine the impact of macroeconomic factors on CO₂ emissions, taking into account the entire available time, which will allow the formation of a more accurate correlation and regression relationship. In addition, those scientific papers that cover a long period are usually devoted to the problems of one particular region or country, and research is conducted

either at different intervals or using different economic and mathematical models, or parameters are taken into account, calculated by different methods, which makes it impossible to make a comparative analysis of several regions of the world. This is also one of the gaps that this study will address.

2. Research Methodology

We assume that the volume of carbon dioxide emissions into the air depends on certain macroeconomic factors (gross domestic product, exports, imports, inflation, and unemployment). The analysis will be carried out using the detection of the relationships and quantitative regularity between “CO₂ emissions” (resulting variable) and “exports”, “imports”, “inflation”, “unemployment” (explanatory variables).

The first step of the study is to build a graphical display of the selected data and analyze their dynamics. The statistical data information database is drawn from World Bank data (World Bank Group, 2021). For a correlation and regression analysis, a sample of statistical data was formed for the period 1970-2020.

The volume of carbon dioxide emissions into the air was selected as a dependent variable according to the purpose of the study, and the following macroeconomic indicators were selected as independent variables: gross domestic product, exports, imports, inflation, and unemployment.

There is no functional mathematical relationship between all these macro indicators, but if relevant statistical data are available, it is possible to hypothesize the existence of a correlation and regression relationship between these macroeconomic factors and CO₂ emissions.

The most important step in econometric analysis is to assess the correlation between the dependent variable and the independent ones. Therefore, the second step is to form a correlation matrix to evaluate the relationship between factors. The STATISTICA software was used to form a correlation matrix and calculate the parameters of a regression equation, which is used mainly for a time-oriented econometric analysis.

The third step is to form a regression equation. Regression analysis methods make it possible to estimate the density of the relationship between features and to form an idea of the type of this relationship in the form of an equation describing the dependence between the average value of one dependent feature and the values of independent factors, the impact of which on the dependent feature is currently being tested.

The evaluation of the econometric models was performed using the least squares (MLS) method. The coefficient of determination and Fisher's criterion are determined for checking the quality of econometric models.

3. Results and Discussion

CO₂ emissions in the EU had been declining since 2007, but since 2014 this trend has been changed, suggesting that all environmental, social, and economic processes that take place within the framework of the regional association of the EU have negatively affected the environmental indicator of CO₂ emissions into the air. Gross domestic product, exports,

imports, inflation increased during the study period, and unemployment fluctuated in the range of 7-12% after the 1990s.

Therefore, the dependent variable in our research is CO₂ emissions; the independent variables include GDP, exports, imports, inflation, and unemployment.

A correlation matrix has been developed to assess the existence of a relationship between CO₂ emissions and EU macroeconomic indicators (Table 1).

The correlation matrix allowed the researchers to obtain the following results:

1. The correlation between CO₂ emission and exports is -0.800564.
2. The correlation between CO₂ emission and gross domestic product is -0.712911.
3. The correlation between CO₂ emission and imports is -0.7737708.
4. The correlation between CO₂ emission and inflation is 0.692936.
5. The correlation between CO₂ emission and unemployment is 0.147329.

Table no. 1. Correlation matrix of the relationship between indicators for the EU

	CO2 emissions (kt)	Inflation, consumer prices (annual %)	Imports of goods and services (current US\$)	Exports of goods and services (current US\$)	Unemployment (% of the total labor force)	Gross domestic product (current US\$)
CO2 emissions (kt)	1.000000	0.692936	-0.773708	-0.800564	0.147329	-0.712911
Inflation, consumer prices (annual %)	0.692936	1.000000	-0.688553	-0.708047	0.029955	-0.669505
Imports of goods and services (current US\$)	-0.773708	-0.688553	1.000000	0.998397	-0.397123	0.985336
Exports of goods and services (current US\$)	-0.800564	-0.708047	0.998397	1.000000	-0.381715	0.979300
Unemployment (% of the total labor force)	0.147329	0.029955	-0.397123	-0.381715	1.000000	-0.356074
Gross domestic product (current US\$)	-0.712911	-0.669505	0.985336	0.979300	-0.356074	1.000000

Source: calculated by the authors

According to the analysis of the indicators by the authors, it can be concluded that exports and imports, GDP of the EU are negatively related to CO₂ emissions, while inflation and unemployment are positively correlated with CO₂ emissions. Therefore, due to higher correlation coefficients, it can be predicted that the regression equation will be more significant for the EU. To avoid the problem of multicollinearity, i.e. the presence of correlation between independent variables, a regression equation without GDP is constructed (Table 2).

Table no. 2. Parameters of the multiple regression equation of the dependence of CO₂ emissions on macroeconomic indicators in the EUDependent Variable: CO₂ emissions (kt)

Sample (adjusted): 1990-2020

Method: Least Squares

Included observations: 31

Variables	Coefficient	Standard error	t-Statistic	Probability
Exports of goods and services (current US\$)	-1E-06	1.77E-07	-5.71411	5.16E-06
Imports of goods and services (current US\$)	9.95E-07	1.89E-07	5.27537	1.63E-05
Inflation, consumer prices (annual %)	-10659.8	18704.67	-0.5699	0.573637
Unemployment (% of total labor force)	-9397.2	15977.77	-0.58814	0.561511
C	3724916.3157	218963.1	17.012	0.0000
Multiple R	0.92096235			
R-squared	0.84817165			
Adjusted R-squared	0.82481344			
S.E. of regression	103933.08064			
F-statistic	36.31150			
Prob(F-statistic)	0.000000			

The multiple regression equation is as follows:

$$\text{CO}_2\text{_EMISSIONS} = 3724916.3157 - 1\text{E-}06 * \text{EXPORTS} + 9.95\text{E-}07 * \text{IMPORTS} - 10659.8 * \text{INFLATION} - 9397.2 * \text{UNEMPLOYMENT} \quad (1)$$

The quality of the econometric model was verified using the coefficient of determination and Fisher's test.

The value of the coefficient of determination ($R^2 = 0.84$) shows that 84% of the value of CO₂ emissions are determined by the values of exports, imports, inflation, unemployment, and 16% are determined by other factors. This value is greater than that of the regression equation for the United States. The authors can conclude that the regression equation for the EU better explains CO₂ emissions in the air and the change in their dynamics. According to the value of R^2 , the accuracy of selection of indicators for the model is quite significant.

Estimated value of Fisher's criterion $F_{\text{est}} = 36.31150$. Tabular value of Fisher's criterion $F_{\text{tab}} = 2.74$. Confidence probability for this case $P = (1 - 0.05) = 0.95$. The adequacy of the model is indicated by the excess of the estimated value over the tabular one.

According to the regression equation, the following conclusions can be drawn:

1. If all the independent variables equal zero, CO₂ emissions in the EU will be 3724916.3157 kt.
2. If export increases by \$1, CO₂ emissions will decrease by 1E-06 kt.
3. If import increases by \$1, CO₂ emissions will increase by 9.95E-07 kt.

4. If inflation increases by 1%, CO₂ emissions will decrease by 10659.8 kt. According to the regression equation, this figure is insignificant (Prob. > 0.05).

5. If unemployment increases by 1%, CO₂ emissions will decrease by 9397.2 kt. According to the regression equation, this figure is insignificant (Prob. > 0.05).

To test the impact of GDP on CO₂ emissions, a regression equation was developed, in which the dependent variable is CO₂ emissions, and the independent variable is the EU GDP (Table 3). When forming the regression equation, GDP was excluded.

Table no. 3. Parameters of the multiple regression equation of the dependence of CO₂ emission on GDP in the EU

Dependent Variable: CO₂ emissions (kt)

Sample: 1970-2020

Method: Least Squares

Included observations: 51

Variables	Coefficient	Standard error	t-Statistic	Probability
Gross domestic product (GDP) (current US\$)	-4.6E-08	6.14E-09	-7.49627	0.000000
C	3796537	58343.31	65.07237	0.000000
Pearson's r	0.730886			
R-squared	0.534194			
Adjusted R-squared	0.524688			
S.E. of regression	228001.8			
F-statistic	56.19401			
Prob(F-statistic)	0.000000			

The relationship between the indicators studied is direct and high-density. The correlation coefficient $r = 0.730886$. The value of the coefficient of determination ($R^2 = 0.53$) proves that 53% of the value of CO₂ emissions is determined by the values of the gross national product, and 47% are determined by other factors. According to the value of R^2 , the accuracy of the selection of indicators for the model is average.

Estimated value of Fisher's criterion $F_{est} = 56.19401$. Table value of Fisher's criterion $F_{tab} = 4.03$. Confidence probability for this case $P = (1 - 0.05) = 0.95$. The adequacy of the model is indicated by the excess of the estimated value over the tabular one. We have the conclusion that if the GDP increases by \$1, CO₂ emissions will decrease by 4.6E-08 kt.

The relationship between CO₂ emissions and gross domestic product (GDP) is constructed in the form of the third degree polynomial spline (a non-linear regression equation). This allows the accuracy of the model to increase ($R^2 = 0.64$) (Figure 1). The multiple regression equation is as follows:

$$CO2_emissions = 3.3651E6 + 2.0207E-7 * GDP - 3.2239E-20 * GDP^2 + 1.1584E-33 * GDP^3(2)$$

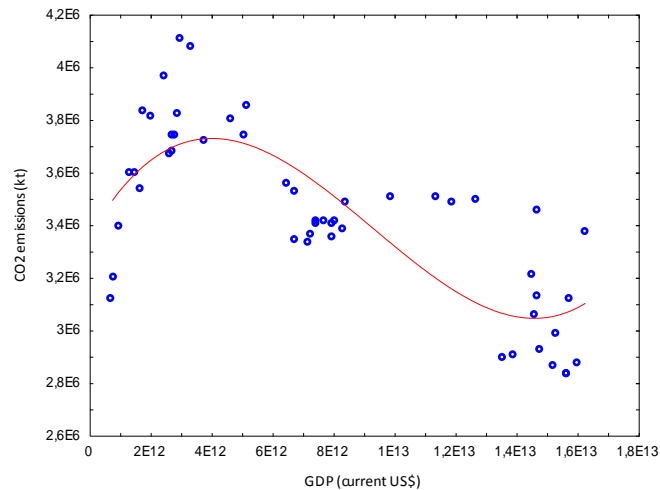


Figure no. 1. Dependency graph of CO₂ on GDP

Therefore, to reduce CO₂ emissions, the EU must improve its economic performance. One can conclude that the current activity of the EU aims to improve the environmental situation.

Conclusions

Managerial decisions to regulate the level of carbon dioxide emissions into the air by EU countries are made based on empirical data of regional characteristics of the impact of macroeconomic indicators on CO₂ emissions. In this study, we used regression models to assess the impact of explanatory variables (gross domestic product, exports, imports, inflation, and unemployment) on the resulting indicator (CO₂ emissions) in the EU region.

The results of this study confirm our hypothesis, i.e. the carbon dioxide emission volume is dependent on macroeconomic indicators. The formation of correlation matrices allowed us to obtain the following results: i) the correlation relationship between the volume of CO₂ emissions and the volume of exports is high and negative for the EU region; ii) the correlation relationship between the volume of CO₂ emissions and GDP is high and negative for the EU region; iii) the correlation relationship between the volume of CO₂ emissions and the volume of imports is high and negative for the EU region; iv) the correlation relationship between the volume of CO₂ emissions and the inflation rate is high and positive for the EU region; and v) the correlation relationship between the volume of CO₂ emissions and the unemployment rate is low and positive for the EU region.

The practical significance of this study is that governments can use the results of an analysis to strike the optimal balance between increasing economic growth and achieving a moderate increase in or reduction in greenhouse gas emissions. Knowing how increasing or decreasing CO₂ emissions affect economic development, countries can use a scientific approach when choosing effective instruments for state regulation of greenhouse gas emissions; for example, in determining the optimal carbon tax rate for industrial pollutants, setting quotas for buying or selling permits for CO₂ emissions, establishing foreign economic restrictions (duties, embargoes, etc.) while exporting or importing environmentally hazardous goods, etc. The

economic state of the regions of the world depends on the ecological situation. When forecasting mechanisms are formed, it is necessary to take into account all possible changes in the global ecological situation. For this reason, countries can use our findings to forecast the level of economic development and macroeconomic indicators in different environmental policy scenarios.

The conclusions of this study are as follows: With a decrease in the GDP of the EU, CO₂ emissions will increase and vice versa. The reason is that the EU has spent a significant amount of resources on improving environmental conditions. This is confirmed by expert forecasts that global CO₂ emissions will increase annually (Andrews, 2018) and that the GDP of the world's regions will increase accordingly (Trading Economics, 2021).

Among the limitations of this study, it should be noted that other factors also affect the level of CO₂ emissions that were not taken into account in the study. As such, for the purposes of further research, it would be worth considering a larger set of not only macroeconomic indicators, but also social, environmental, technological, and other factors, to identify a set of the most influential determinants and to develop tools for effective decision-making in the field of solving environmental problems related to CO₂ emissions.

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