The Impact of Economic Development on Environmental Pollution in Romania. A Research Based on Kuznets' Environmental Curve

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Abstract

The current paper aims to study the application of this theory in the current economic context in Romania, contributing to filling the gaps in the existing research on this subject. Thus, in the practical part of the paper, a non-linear regression model was created using the volume of greenhouse gases as the dependent variable (representing environmental degradation) and the GDP per capita as the independent variable (representing the economic development of the country). The results suggest a significant impact of economic development on environmental pollution in Romania between 1990 and 2022. The positive correlation between GDP per capita and greenhouse gas emissions, as indicated by the positive coefficient of DPIB (-1), underscores the importance of managing economic growth sustainably to mitigate environmental impacts. This finding aligns with Kuznets' environmental curve theory, which proposes that initially, rising per capita income can result in higher pollution and greenhouse gas emissions as developing nations prioritize economic advancement over environmental concerns. However, as economies progress and mature, there is an opportunity for the adoption of cleaner technologies, the implementation of environmental regulations, and investments in sustainability, potentially leading to a reduction in both greenhouse gas emissions and pollution.

Keywords: Kuznets' environmental curve, economic development, environmental degradation, inequality

JEL classifications: O12, F63

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1. Introduction

According to the theory of the theory behind environmental Kuznets curve, environmental degradation initially increases as a country develops economically, but eventually decreases after reaching a certain income level. In other words, the relationship between economic development and environmental quality follows an inverted U-shaped curve, where pollution levels first rise with economic growth and then decline as income levels reach a certain threshold. The theory implies that as countries become wealthier, they allocate more resources towards environmental protection and adopt cleaner technologies, leading to a decrease in pollution levels. One key implication of the theory is its potential impact on policy formulation. By recognizing that economic growth and environmental sustainability need not be at odds, policymakers can adopt strategies that foster sustainable development while also supporting economic prosperity. This understanding can pave the way for the

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implementation of measures that strike a balance between economic progress and environmental protection. Moreover, the concept of the environmental Kuznets curve underscores the importance of transitioning towards a green economy. In an era marked by pressing environmental challenges such as climate change and resource depletion, the environmental Kuznets curve encourages countries to explore avenues for sustainable growth. This may involve investing in clean technologies, promoting innovation in environmental solutions, and adopting practices that minimize ecological footprints. The environmental Kuznets curve highlights the role of technology and innovation in driving environmental improvements. As countries approach the turning point where environmental degradation begins to diminish, opportunities arise for developing and deploying green technologies. This can spur research and development efforts aimed at creating sustainable solutions that benefit both the economy and the environment.

Additionally, the global relevance of the environmental Kuznets curve underscores the importance of international cooperation in addressing environmental issues. Collaboration on a global scale becomes essential as nations strive to achieve a point where environmental degradation declines.

This theory was studied in various articles (over 200 in the last 25 years), which included an analysis of the variables in Romania as well, among other countries. However, some papers considered carbon dioxide emissions to be a more representative variable for environmental degradation (Zortuk and Çeken, 2011). Other variables used to measure this aspect were: industrial wastewater discharge (Liang and Yang, 2019), water consumption (Hao, Hu and Chen, 2019), nitrous oxide levels (Adzawla, Sawaneh, and Yusuf, 2019) or footprint components (Aydin and Esen, 2019).

By introducing a larger and varied set of indicators in the model to measure economic development and environmental degradation, the research can ensure a more complex analysis and a more specific set of results. However, even if the current paper contains only two variables (GDP per capita and the volume of greenhouse gases), based on the period for which the database was created (1990-2022), the results are considered to be relevant.

2. Literature review

In their article published in 2022, Leal Patricia and Marques Antonio discuss the gaps in the environmental Kuznets curve analysis such as the focus only on production and oversight of the impact of imported goods consumption on the environment. It also discusses how factors like technological progress, climate finance, and energy transition could influence the assessment of the environmental curve. The authors also emphasize the importance of considering additional variables, the type of analysis methods employed, and the different factors influencing the validation of the EKC in various contexts.

Another relevant paper (Ajmi et al, 2023) mentions that the EKC hypothesis, based on the idea of an inverted U-shaped relationship between economic growth and environmental degradation, has been a prominent framework in environmental economics. The hypothesis suggests that environmental degradation initially increases with economic growth, reaches a turning point, and then decreases as the economy progresses. However, in the article, the authors also point out that the relationship between economic growth and environmental degradation as predicted by the EKC hypothesis is not always straightforward. The empirical evidence supporting the EKC hypothesis has been mixed, with conflicting results noted in the literature. This suggests that the relationship between economic growth and environmental degradation is complex and influenced by various factors.

The theoretical criticism corresponding to Fache et al (2015) challenges the underlying assumptions and hypotheses of the EKC, while the econometric criticism questions the empirical evidence and statistical models used to support the theory. The authors also review the pollution axis and economic growth axis of the EKC to assess its overall validity.

An article corresponding to the National Bureau of Economic Research (1999) discusses the relationship between economic development and inequality, specifically focusing on the research findings by NBER Research Associate Robert Barro. Barro's analysis shows that there is a U-shaped relationship between inequality and growth during the process of economic development. The article indicates that higher levels of inequality tend to reduce economic growth in poorer countries with income per capita less than $2,000. On the other hand, in richer countries with income per capita of more than $2,000, higher levels of inequality can encourage economic growth. Furthermore, the adoption of new technologies plays a significant role in shaping this relationship. Technological innovations tend to initially increase inequality as only a few benefit from the advanced sector's higher incomes. However, as more people adopt the new technology, inequality eventually decreases.

Another article (Shen and Zhaob, 2023) explores the relationship between economic development and inequality by investigating how income inequality affects economic growth at different income levels. It finds that the impact of income inequality on economic growth varies with income levels. In low-income countries, inequality tends to impede growth, while in high-income countries, the effect of inequality on growth becomes insignificant. Additionally, the study highlights the importance of considering country differences, such as economic systems, religious beliefs, and savings habits, in understanding the relationship between inequality and economic growth.

In his research, the author Seher Gülşah Topuz (2022) discusses the relationship between economic development and income inequality in the context of various theoretical transmission channels. They explain that income inequality can have both positive and negative impacts on economic growth, depending on the country's economic development level. In the early stages of development, inequality might be beneficial for economic growth as physical capital returns are higher than human capital. However, in later stages of development, inequality can reduce economic growth due to credit constraints, with the importance of human capital increases. Ultimately, in more advanced stages of development, income distribution might not significantly affect economic growth. This perspective highlights the role of a country's income level in shaping the impact of income inequality on economic growth.

As well, authors Mdingi and Ho (2021) examined the relationship between income inequality and economic growth by considering various transmission mechanisms. One of the mechanisms discussed is the level of economic development. Early researchers, such as Kuznets, documented that the relationship between income inequality and economic growth depends on the developmental stage of the economy. They found that there is a differential relationship between income inequality and growth, with a positive relationship during the early stage of economic development and a negative relationship during the mature stage. This notion is based on the shifts of labor from one sector to another as the economy develops. As labor moves from the agricultural sector to other sectors, individuals in the agricultural sector may experience increased income inequality. However, as the economy matures and more labor shifts to sectors using new technology, income inequality may decrease.

Additionally, a document published by the OECD (Cingano, 2014), highlights the effects of inequality on skills development, educational outcomes, and economic growth, emphasizing the importance of addressing inequality to promote inclusive employment and access to public services. It also suggests policy interventions such as reforms to tax and benefit policies, improvements in access to education and training, and strategies to enhance skills development for low-skilled individuals. The document concludes that reducing inequality can not only make societies fairer but also contribute to higher economic growth and better social mobility.

3. Research Questions/Aims of the Research

The current research will focus on analyzing the economic development and environmental degradation in Romania. To create the model, we will use the theory of the environmental Kuznets curve, presented in the previous part of the paper.

Based on this theory, there is a non-linear relationship between the two variables, which indicates the need to create a non-linear regression model.

To create the model, we considered it relevant to include GDP per capita as the independent variable to measure the economic development of the country and the volume of greenhouse gases as the dependent variable, measuring environmental degradation. The database was created using the data available on Eurostat corresponding to the last 33 years (1990-2022) for Romania.

The analysis of the indicator represented by the volume of greenhouse gases (GHG) was considered relevant, as it can quantify the pollution and degradation of the environment due to the impact these gases have on climate change. Greenhouse gases such as carbon dioxide (CO2), methane (CH4), and nitrogen oxides (NOx) trap heat in the atmosphere and contribute to rising global temperatures, a phenomenon known as global warming. The increase in the concentration of these gases in the atmosphere is the result of human activities such as the burning of fossil fuels, extensive deforestation, and intensive agricultural practices. These activities lead to increased greenhouse gas emissions, leading to significant climate change such as melting glaciers, rising sea levels, and a variety of impacts on ecosystems and wildlife.

The second variable included in the analysis, GDP per inhabitant is representative in the context of economic growth and development, as it is the representation of the standard of living of the population of a country. The value of this indicator indicates the level of resources and goods available per person, directly influencing how people can meet their needs and improve their quality of life. An increase in GDP per capita can be associated with better accessibility to education, healthcare, housing, and other facilities, leading to a more comfortable life for residents. Also, the evolution of GDP per capita over time is an economic growth indicator of a country. An increase in this indicator suggests that the nation's economy is expanding, which may be the result of increased productivity, investment in infrastructure, innovation, and other factors that spur economic progress. This growth can help reduce poverty, create jobs, and improve the standard of living of the population.

The research question considered is the following: is there a relationship between the degradation (pollution) of the environment and economic growth in the sense of the increase of degradation in the conditions where the economic growth of a country goes through significant economic growth at the level of Romania? The objective of the research logically follows from the presented research question, that of determining if there is a relationship between environmental degradation or pollution and economic growth in Romania in the period 1990-2022. Also, based on the above-indicated research question, we can conclude that the current study has two hypotheses:

H0: There is no significant relationship between the degradation (pollution) of the environment and economic growth in the sense of the increase of degradation in the conditions where the economic growth of a country goes through significant economic growth at the level of Romania.

H1: There is a significant relationship between the degradation (pollution) of the environment and economic growth in the sense of the increase of degradation in the conditions where the economic growth of a country goes through a significant economic growth at the level of Romania.

4. Research Methods

The first step in creating the non-linear regression model was to test if the two-time series (represented by the two variables included in the analysis) are stationary in levels or at the first or second difference. Therefore, the ADF test was performed for each of the variables. The first analysis was performed for the volume of greenhouse gases (GES). Based on the results obtained in Eviews for the ADF test, it can be seen that the obtained test statistic is -2.98, with an associated probability of 0.1514 (15.14%). Since the value of the ADF test obtained is not greater in absolute value (2.98) than the absolute critical value of the previously indicated t-tests (4.28, 3.56, and 3.21), the null hypothesis of this test (H0) can be rejected. In other words, the level data within the time series representing the volume of greenhouse gases evolves non-stationary.

Figure 1. The results of the ADF test in levels and at first difference for the GES variable

Null Hypothesis: GES has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.987952	0.1514
Test critical values:	1% level	-4.284580	
	5% level	-3.562882	
	10% level	-3.215267	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GES)
Method: Least Squares
Date: 06/05/24 Time: 14:37
Sample (adjusted): 1992 2022
Included observations: 31 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GES(-1)	-0.331599	0.110979	-2.987952	0.0059
D(GES(-1))	0.365139	0.109669	3.329472	0.0025
C	24.38268	8.592478	2.837677	0.0085
@TREND("1990")	-0.535967	0.191063	-2.805184	0.0092

R-squared	0.434630	Mean dependent var	-1.683871
Adjusted R-squared	0.371811	S.D. dependent var	3.342264
S.E. of regression	2.649025	Akaike info criterion	4.906174
Sum squared resid	189.4680	Schwarz criterion	5.091205
Log likelihood	-72.04570	Hannan-Quinn criter.	4.966490
F-statistic	6.918771	Durbin-Watson stat	1.509557
Prob(F-statistic)	0.001328		

Null Hypothesis: D(GES) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.500022	0.0000
Test critical values:	1% level	-2.641672	
	5% level	-1.952066	
	10% level	-1.610400	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GES,2)
Method: Least Squares
Date: 06/05/24 Time: 15:05
Sample (adjusted): 1992 2022
Included observations: 31 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GES(-1))	-0.573563	0.104284	-5.500022	0.0000

R-squared	0.491563	Mean dependent var	0.603226
Adjusted R-squared	0.491563	S.D. dependent var	4.219912
S.E. of regression	3.008998	Akaike info criterion	5.072818
Sum squared resid	271.6221	Schwarz criterion	5.119075
Log likelihood	-77.62868	Hannan-Quinn criter.	5.087897
Durbin-Watson stat	1.571201		

Source: Authors personal interpretation from Eviews

To eliminate the non-stationarity of the time series, the application of the ADF test was continued, this time including the difference operator (by selecting 1st difference in the test application options in Eviews). Thus, by applying this operator, the following results indicated below are obtained. In this case, the result of the ADF test has a value of -5.279, whose absolute value is worse than the absolute critical values for the significance thresholds of 1%, 5%, and 10%, respectively. This indicates that the time series is stationary at a first difference level.

By implementing the same methods, we observed that the GDP time series was also nonstationary in levels, and stationary in the first difference.

Figure 2. The results of the ADF test in levels and at first difference for the GDP variable

Null Hypothesis: PIB has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		1.210503	0.9975
Test critical values:	1% level	-3.653730	
	5% level	-2.957110	
	10% level	-2.617434	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(PIB)
Method: Least Squares
Date: 06/11/24 Time: 14:20
Sample (adjusted): 1991 2022
Included observations: 32 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PIB(-1)	0.033442	0.027627	1.210503	0.2355
C	20.52703	166.6974	0.123139	0.9028

R-squared	0.046569	Mean dependent var	211.0625
Adjusted R-squared	0.014788	S.D. dependent var	312.8148
S.E. of regression	310.4932	Akaike info criterion	14.37466
Sum squared resid	2892180.	Schwarz criterion	14.46627
Log likelihood	-227.9946	Hannan-Quinn criter.	14.40503
F-statistic	1.465318	Durbin-Watson stat	2.151889
Prob(F-statistic)	0.235537		

Null Hypothesis: D(PIB) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.513194	0.0001
Test critical values:	1% level	-3.661661	
	5% level	-2.960411	
	10% level	-2.619160	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(PIB,2)
Method: Least Squares
Date: 06/11/24 Time: 14:34
Sample (adjusted): 1992 2022
Included observations: 31 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(PIB(-1))	-1.015639	0.184220	-5.513194	0.0000
C	204.4161	68.40307	2.988406	0.0057

R-squared	0.511746	Mean dependent var	-2.774194
Adjusted R-squared	0.494910	S.D. dependent var	447.7632
S.E. of regression	318.2240	Akaike info criterion	14.42573
Sum squared resid	2936730.	Schwarz criterion	14.51824
Log likelihood	-221.5988	Hannan-Quinn criter.	14.45589
F-statistic	30.39531	Durbin-Watson stat	1.801153
Prob(F-statistic)	0.000006		

Source: Authors personal interpretation from Eviews

Thus, as a result of confirming the stationarity of the series as a result of the inclusion of the differentiation operator of degree 1, the DGES and DPIB series were created in Eviews containing the values obtained for this variable as a result of the implementation of the differentiation operator.

To test the cointegration between the two-time series in the first difference (DGES and DPIB), the Johansen test is applied. In the abscissa of the obtained results, as can be seen, it is necessary to choose the last assumption (that the model is a quadratic one and the number of lags should be 2). The null hypothesis of the test assumes that there is no cointegration between the two series, therefore there is no long-run relationship between the two variables. In this sense, if within the obtained results, the probability is less than or equal to 5%, then the null hypothesis must be rejected. Thus, as can be seen below, the obtained probabilities (0.0022 and 0.010) are lower than the 5% threshold, which leads us to reject the null hypothesis and accept the fact that there is cointegration between the two-time series. At the same time, the same result is also supported by the values obtained for Trace Statistics, which register values higher than the critical values (27.25>18.38 and 6.5>3.84).

Next, the error correction coefficient indicates the speed of adjustments at which the model will restore equilibrium. Thus, the coefficient related to the independent variable (DPIB) is negative, which indicates that there is a convergence from short-term dynamics to long-term equilibrium. However, the coefficient is not statistically significant, as it is less than 2. This indicates the absence of significant adjustments towards the long-run equilibrium in any disequilibrium situation.

In the next part of the research, as a result of obtaining the cointegration equation, and its estimation in Eviews we can conclude that in the equation, the coefficient C(5) (the long-run coefficient) is positive and statistically significant, indicating that there is a long-run causality between GDP per capita and the volume of greenhouse gases (DGES). However, the positive sign of the coefficient indicates the dynamics of the relationship concerning the equilibrium position. Next, the short-term coefficient (C6) indicates that a one percent increase in the value of the DGES variable in question leads to a 0.001% decrease in the DPIB variable. Likewise, the one percent increase in the DPIB variable leads to a 0.23% increase in the DGES variable. In the case of the created equation, C8 is the constant or the intercept.

At the same time, the value of the F test related to this equation indicates the existence of a statistical significance, and the DW statistic indicates the absence of autocorrelation. However, according to the obtained probabilities, it can be stated that only the C5 coefficient is statistically significant.

Figure 3. Interpretation of the model equation coefficients

Dependent Variable: D(DGES)
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 06/11/24 Time: 15:38
Sample (adjusted): 1993 2022
Included observations: 30 after adjustments
D(DGES) = C(5)*(DPIB(-1) - 340.03672137*DGES(-1) - 767.128603377)
+ C(6)*D(DPIB(-1)) + C(7)*D(DGES(-1)) + C(8)

	Coefficient	Std. Error	t-Statistic	Prob.
C(5)	0.001967	0.000564	3.486986	0.0018
C(6)	-0.001172	0.001256	-0.932667	0.3596
C(7)	0.237830	0.139521	1.704613	0.1002
C(8)	0.012368	0.564501	0.021910	0.9827

R-squared	0.355990	Mean dependent var	0.186667
Adjusted R-squared	0.281681	S.D. dependent var	3.585674
S.E. of regression	3.038992	Akaike info criterion	5.184495
Sum squared resid	240.1223	Schwarz criterion	5.371321
Log likelihood	-73.76742	Hannan-Quinn criter.	5.244262
F-statistic	4.790674	Durbin-Watson stat	1.992436
Prob(F-statistic)	0.008685		

Source: Authors personal interpretation from Eviews

Thus, the equation can be rewritten in the following form:
D(DGES) = 0.0019*(DPIB(-1) - 340.03672137*DGES(-1) - 767.128603377) – 0.0011* D(DPIB(-1)) + 0.23)*D(DGES(-1)) + 0.012

5. Findings and discussions

Based on the equation presented, which explores the relationship between GDP per capita and the volume of greenhouse gases, we can see a significant impact of economic growth on greenhouse gas emissions. The positive coefficient associated with DPIB(-1) suggests that an increase in GDP per capita is associated with a concomitant increase in the volume of greenhouse gases, highlighting the importance of sustainable management of economic growth to reduce environmental impacts.

This observation can be related to Kuznets' environmental curve theory, which suggests that initially, an increase in per capita income can lead to an increase in pollution and greenhouse gas emissions, as developing societies focus on economic growth and can ignore the environmental impact. But as economies develop and become more advanced, there is the potential for them to start adopting cleaner technologies, implementing environmental policies, and investing in sustainability, which could lead to a decrease in greenhouse gas emissions greenhouse and pollution.

The complex interactions in the equation, such as the interaction terms reflecting the mutual influences between DPIB and DGES, emphasize the importance of an integrated approach in managing the relationship between economic growth and the environment. These interactions could influence the evolution of the relationship between GDP per capita and greenhouse gas emissions over time, reflecting the complex dynamics of economic development and environmental impact.

Finally, based on the results of the Kuznets equation and environmental curve theory, it is evident that the sustainable management of economic growth and greenhouse gas emissions is a crucial challenge for contemporary societies. Therefore, it can be concluded that the analysis carried out led to obtaining an affirmative answer regarding the research question initially drawn.

6. Conclusions

The theory of the Environmental Kuznets Curve (EKC) offers valuable insights into the intricate relationship between economic development and environmental quality. According to this theory, environmental degradation tends to increase as a country develops economically, reaching a peak before declining once a certain income level is achieved. This inverted U-shaped curve signifies that as nations become wealthier, they are more likely to prioritize environmental protection and adopt cleaner technologies, ultimately leading to a reduction in pollution levels. However, the EKC theory is not without its criticisms and challenges. Some researchers question its underlying assumptions, hypotheses, and empirical evidence, leading to mixed results in the literature. The relationship between economic growth and environmental degradation is complex and multifaceted, influenced by various factors that warrant further exploration and analysis.

In parallel, the relationship between economic development and income inequality presents another dimension of study. Research indicates that the impact of inequality on economic growth varies with a country's income level and developmental stage. Different transmission mechanisms, such as shifts in labor and technological advancements, play a crucial role in shaping this relationship and highlight the importance of addressing inequality to promote inclusive growth. Addressing income inequality requires targeted policy interventions, including tax reforms, improvements in education access, and strategies for skills development. These measures not only contribute to reducing inequality but also foster higher economic growth and enhance social mobility, making societies fairer and more inclusive. The intricate interplay between economic development, environmental degradation, and income inequality underscores the complexity of sustainable development. By considering various factors and adopting appropriate policy measures, countries can navigate these challenges toward achieving a harmonious balance between economic progress, environmental protection, and social equity. Only through concerted efforts and collaborative actions can we pave the way for a more sustainable and prosperous future for all.

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