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Research Article

Towards a greener Albania: Balancing economic growth and environmental sustainability through global insights

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Abstract

This paper investigates Albania's economic development trajectory through the lens of sustainable growth, drawing comparisons with nations like South Korea and Costa Rica, which have successfully aligned economic growth with environmental sustainability, while aiming to avoid paths exemplified by Brazil and India. Using econometric models, this study evaluates Albania's GDP growth dependencies through traditional growth-oriented versus sustainability-focused macroeconomic frameworks, including Green Keynesianism and Ecological Macroeconomics. Key considerations include the Environmental Kuznets Curve (EKC) hypothesis, the role of income in social outcomes, and the principle of strong sustainability in natural capital management. Findings suggest that Albania's path to sustainable growth will require a multi-faceted approach: reinforcing environmental regulations, incentivizing green technology, fostering international cooperation, and promoting targeted R&D investment. By aligning policies with sustainable practices, Albania has the potential to achieve further economic growth without compromising its environmental assets.

Keywords: Sustainable Development, Environmental Kuznets Curve (EKC), Renewable Energy Integration, Green Keynesianism, Albania, Economic Growth and Environmental Models.

1. Introduction

Between 1997 and 2000, the extent of virgin forests in Albania declined dramatically from 7% to just 1% of the national forest fund (Diku & Shuka, 2017). This reduction, corroborated by World Bank reports, highlights unsustainable exploitation of natural resources, particularly deforestation. While tree cutting does not directly emit CO_2, it severely limits the sequestration capacity of carbon in nature, aggravating climate change. These findings emphasize the critical need for a comprehensive strategy to manage natural capital responsibly. The assumption that Albania can rely solely on its natural resources to achieve economic prosperity is not only misleading but also detrimental. Economic development requires transformative value addition to goods and services rather than the mere export of raw materials to fuel industrial machinery in developed countries. Lessons from Norway's sovereign wealth fund illustrate that sustainable natural resource management necessitates decades of disciplined governance and administration to ensure equitable benefits for all citizens.

The post-COVID-19 economic recovery has prompted questions about the relationship between rapid GDP growth and CO_2 emissions. Data from the World Bank suggests that countries experiencing steeper GDP growth trends post-2021 are worth investigating for CO_2-related studies. Rapid economic expansion during this period likely corresponds to intensified consumption of natural resources. For instance, countries with accelerated growth often display trends that diverge from sustainability, as observed in economic data from 2018 onward. Albania's case underscores the importance of balancing GDP growth with environmental preservation, drawing inspiration from sustainable development models such as BiH's.

Responsible use of natural resources is pivotal for achieving SDG 12, which advocates sustainable production and consumption. Since the mid-1990s, global natural capital has grown by an average of 26.8%, yet many countries, including Albania, have struggled to decouple economic growth from resource depletion. Analysis of data from the Sustainable Development Goals (SDG) platform reveals that Albania transitioned from unsustainable to sustainable development only after 2012. The four-year period of stability (2012–2016) highlights the potential for sustained GDP growth without compromising natural capital. However, recent trends suggest that Albania's GDP growth has come at the expense of its natural resources, mirroring challenges faced by countries like the Maldives, where economic growth has been unsustainable. Comparisons with neighboring Bosnia and Herzegovina, which demonstrates one of the most sustainable growth trajectories in the region, provide valuable lessons for Albania. By fostering a green policy framework and attracting direct investments, Albania has the potential to advance its industry, protect the environment, and transition to the High-Income group of countries.

Ngone Mirimi (2024) explores the nuanced relationship between economic growth and environmental sustainability in developing economies, emphasizing how the balance between economic growth and environmental sustainability often depends on governmental policies, the implementation of green technologies, and international support. The analysis reveals that while the Environmental Kuznets Curve (EKC) hypothesis may hold in economies with strong environmental regulations, unchecked growth in resource-dependent economies can lead to persistent environmental degradation, as observed in Brazil and India. Mirimi (2015) recommends tailored economic models that emphasize strong regulations, technological innovation, and global cooperation as critical measures to support sustainable development in these contexts.

Pathiranage (2024) further emphasizes the need for a fundamental shift in economic policies to address the strong link between GDP growth and CO_2 emissions. This study advocates for abandoning traditional growth paradigms in favor of frameworks that integrate sustainability. For high-emission economies, policies should target decoupling growth from emissions through regulations, carbon pricing, and clean technology incentives. Pathiranage also underscores the importance of international cooperation, particularly in supporting developing economies through technology transfer and green financing, noting that customized policies are crucial as universal approaches may prove ineffective.

In the context of sustainability and competitiveness in a globalized economy, Škuflić, Šokčević, and Bašić (2024) use the Global Competitiveness Index (GCI) and Sustainable Development Goals (SDGs) to examine the intricate relationship between these dimensions. They find that SDG 12 (responsible consumption and production) negatively affects competitiveness due to increased production costs, while SDG 14 (life below water) positively influences it. This disparity indicates that the GCI does not fully account for environmental impacts, prompting the authors to call for a revision of the index to better reflect sustainable competitiveness, aiming for growth in market share and GDP per capita without compromising environmental resources.

Harris (2013) examines "Green Keynesianism," which advocates for government-led investments in green initiatives as a means of stimulating economic growth. Despite criticism from New Classical economists regarding deficit spending, Harris presents evidence that government interventions, particularly during the 2009–10 economic stimulus, can successfully increase aggregate demand and spur economic recovery. Green Keynesianism, as Harris suggests, incorporates sustainability within Keynesian economic frameworks by promoting investments in green infrastructure, renewable energy, and education—efforts that both stimulate growth and align economic output with ecological limits. The challenge, however, remains the political barriers to taxation and government spending, particularly in regions resistant to such fiscal measures.

A more localized perspective on environmental challenges is presented by Alua, Peprah, and Achana (2020), who investigate the effects of climate change on agricultural production in North-East Ghana. Their study, rooted in political ecology, highlights the interplay between environmental, social, and economic factors in intensifying water scarcity and its impact on agricultural productivity. Adaptation strategies include expanding farm sizes, diversifying income sources, and adopting innovative irrigation practices. The authors advocate for interdisciplinary collaboration to effectively address water scarcity and mitigate climate change impacts.

Building on these ideas, Harris (2015) argues for a paradigm shift in macroeconomic education to better address modern issues such as sustainability and inequality. He critiques the limitations of traditional equilibrium-based models and proposes a "green Keynesian" approach that offers diverse economic pathways, including low-carbon and steady-state growth options. This framework aims to actively shape sustainable economic growth through fiscal, monetary, and environmental policies—a significant departure from traditional, growth-centric economic models.

In the global context of agricultural impacts, Lamonaca, Seccia, and Santeramo (2023) analyze climate change's effects on wine production and trade. Their findings indicate that rising temperatures generally enhance production volumes and export values, particularly in major wine-producing regions, while rainfall has a minimal economic impact. The study illustrates how climate change can reshape comparative advantages among wine-producing countries, emphasizing the role of sustainable practices to maintain long-term competitiveness in the sector.

From an Iranian perspective, Naruei et al. (2024) examine climate adaptation strategies among wheat farmers, revealing an average technical efficiency of 82% in Iran's Sistan region. Adaptive practices such as improved irrigation are found to reduce water usage while increasing efficiency. Key influences on efficiency include labor, chemical inputs, and machinery, suggesting that enhanced education, access to credit, and timely weather information are crucial for further improvements. The authors also note the potential conflict between productivity gains and environmental sustainability, advocating for future studies that evaluate the broader social and environmental consequences of adaptation strategies.

Moussaid, Jerry, and Qafas (2023) explore the relationship between water demand and economic growth in Morocco, employing the Tapio Decoupling Index. They observe periods of both strong and weak decoupling, attributing these fluctuations to Morocco's proactive water management policies, such as the Water Strategy 2020 and the Green Morocco Plan. The authors suggest Morocco's water resilience could be bolstered through further measures like desalination and climate-resilient infrastructure, highlighting the importance of a resilience-focused approach in water management.

In their historical analysis of tourism's environmental impact, Buckley and Underdahl (2023) identify six distinct phases: ecology, management, economics, climate, health, and politics. They draw parallels between tourism's expanding influence over public lands and other extractive industries, underscoring concerns about "land grabs" by developers. The authors call for greater transparency and stakeholder involvement in tourism planning to prevent unsustainable exploitation of protected areas.

Dzyuba and Bakalova (2023) provide a bibliometric analysis of computable general equilibrium (CGE) models in resource-dependent economies, emphasizing the growing application of CGE models in environmental and climate studies. Their review highlights the versatility of CGE models in assessing policy impacts across different sectors, making them particularly valuable for developing countries navigating trade-offs between economic growth and sustainability.

Samuel et al. (2024) examine the economic growth-environment nexus in African countries, utilizing the Fixed Effect Model (FEM) to support the EKC hypothesis. Their findings indicate that economic growth initially leads to increased emissions but ultimately fosters better environmental outcomes as income rises. The authors advocate for eco-friendly initiatives and renewable energy investments to promote long-term sustainability, urging policymakers to balance growth and environmental considerations.

Golombek, Greaker, and Hoel (2010) investigate climate policies without government commitment, finding that time inconsistency issues could hinder long-term climate initiatives. They recommend high initial carbon taxes to incentivize R&D in climate technologies, compensating for potential shortfalls in future subsidies. Hoel (2020) further explores the complex role of bioenergy in climate policy, suggesting a nuanced approach that incorporates both taxation and subsidies to address its environmental costs.

In advocating for a shift toward sustainable growth, Harris (2008) proposes an ecological approach to macroeconomics, aligning economic policies with sustainability through "Green Keynesian" strategies. This involves redirecting fiscal and monetary policies to support clean energy investments, resource efficiency, and social welfare, challenging the traditional reliance on material throughput for economic growth.

Van Eynde et al. (2024) critique Environment-Society-Economy (ESE) models for their limited representation of environmental and social indicators. They propose a broader incorporation of variables, from biophysical to socio-economic, to better capture the intricacies of sustainable development and transition pathways. Their work advocates for detailed provisioning systems and intersectional analyses to inform policymaking that prioritizes well-being over GDP growth.

Developing countries, characterized by low per-capita income, often occupy the positive slope of the inverted U-shaped Environmental Kuznets Curve (EKC), indicating a phase where economic growth is associated with heightened environmental degradation. As highlighted by Ashraf and Rehman (2023), the quadratic effect of GDP per capita (GDPC) on CO_2 emissions underscores the critical need for these nations to balance growth with sustainability. Control variables such as the export of goods and services, urban population growth, gross fixed capital formation, and industrialization further exacerbate environmental pressures, reflecting the challenges of achieving economic expansion without detrimental ecological impacts. These findings emphasize the importance of policy interventions that prioritize social progress while mitigating environmental harm. Governments in developing countries must adopt strategies that decouple economic growth from resource depletion and emissions, ensuring that progress in industrialization and trade does not come at the cost of environmental sustainability.

The reviewed literature highlights recurring themes in the intersection of economic growth, environmental limits, and social outcomes. These include:

Traditional Growth-Oriented Models vs. Sustainability-Focused Models: Traditional macroeconomic models prioritize GDP growth, often at the expense of sustainability. Authors like Harris (2008) critique this approach, emphasizing the need to balance economic and ecological concerns.

Decoupling Economic Growth from Environmental Degradation: The EKC hypothesis suggests that environmental degradation initially increases with economic growth before eventually improving. However, critics argue that growth alone is insufficient, advocating instead for models that integrate environmental and social outcomes directly.

Green Keynesianism and Ecological Macroeconomics: Green Keynesianism introduces sustainability into traditional fiscal policies, supporting investments in renewable energy and efficiency. Ecological macroeconomics similarly aims to align economic policy with ecological limits.

Income as a Driver of Social Outcomes: Van Eynde et al. (2024) argue that focusing solely on income per capita obscures other key determinants of well-being, advocating

for a broader approach that integrates socio-economic and environmental factors.
Strong Sustainability and Non-Substitutability of Natural Capital: Traditional models often assume substitutability between natural and economic capital. In contrast, the Doughnut model promotes a "strong sustainability" approach, emphasizing the irreplaceability of natural resources for maintaining human well-being and ecological balance.
Policy Integration and Feedback Mechanisms: Models like Green Keynesianism propose integrating environmental feedback into economic policy, ensuring that ecological impacts are directly addressed through mechanisms like carbon taxes and incentives for renewable energy.
To sum up, while traditional macroeconomic models emphasize perpetual growth, alternative frameworks such as Green Keynesianism, ecological economics, and the Doughnut model argue for shifting the focus from material expansion to sustainable well-being. These models propose policies that directly manage resource use, incentivize renewable energy, and incorporate social outcomes, highlighting the need for a reorientation toward sustainable prosperity.

2. First Model

To examine the relationship between carbon dioxide (CO_2) emissions and Gross Domestic Product (GDP), we applied a model inspired by Heshan Sameera Kankanam Pathiranage. Two simple regressions were conducted to assess the variance explained by GDP and the share of renewable energy in total energy consumption regarding CO_2 emissions. The dependent variable in this analysis is CO_2 emissions, while the independent variables are GDP and the share of renewable energy in the total energy mix, for the years 1990–2021. Both CO_2 emissions and GDP were analyzed in their logarithmic forms and normalized per capita to reflect emissions per person and GDP per person. The model is specified as follows:
$LnCO_2 = \beta\_0 + \beta\_1(X) + e$,
where (X) represents (LnGDP) and the share of renewable energy (REN). Initially, the correlation between per capita CO_2 emissions and per capita GDP is calculated as 0.35, indicating a weak but positive relationship; an increase in one variable suggests an increase in the other. Conversely, a strong negative correlation of -0.77 is observed between per capita CO_2 emissions and the share of renewable energy in the total energy mix. This indicates that a rise in renewable energy's share is strongly associated with a reduction in CO_2 emissions.

Table 1: Correlation Results for CO_2 Emissions, GDP, and Renewable Energy Share

	CO_2
PBB	0.35
Ren	-0.77

Building on the earlier correlation results, we conducted simple regressions to further analyze these above relationships. The findings confirm a statistically significant positive relationship (at the 5% significance level) between CO_2 emissions and GDP. Conversely, a negative relationship is confirmed between CO_2 emissions and the share of renewable energy in the total energy mix. What stands out for Albania, as for many other developing countries, is that the variance in CO_2 emissions is explained more by changes in the share of renewable energy than by changes in GDP. Specifically, approximately 12.35% of the variance in CO_2 emissions is explained by GDP changes, whereas 58.8% of the variance is explained by the share of renewable energy in the total energy mix.

Table 2: Regression Results for CO_2 Emissions, GDP, and Renewable Energy Share

	Coefficient	Prob. P-Value	R^2	Sig. P-Value	Prob. F-Statistic
LNGDP	0.357136	0.0193	0.123581	**	0.019286
EN	-0.019791	0	0.58871	***	0

The regression analysis reveals that when CO_2 emissions are modeled as dependent on GDP and the share of renewable energy, the coefficients are 0.53 for GDP and -0.134 for renewable energy. Both coefficients are statistically significant, indicating that GDP has a positive effect on CO_2 emissions, while an increase in the share of renewable energy has a negative impact. However, due to the presence of unit roots in both variables, the validity of the model is uncertain. Unit root tests using the Augmented Dickey-Fuller (ADF) method confirm that all variables exhibit unit roots at their levels. Consequently, the variables need to be transformed to stationarity by differencing them to the first order.

Table 3: Unit Root Test Results Using Augmented Dickey-Fuller (ADF)

	LNCO2_cap	LNPBB_cap	REN
Order 1	0.8963	0.3975	0.3871
Order 2	0.0001	0.0069	0.001

Unit root tests using the Augmented Dickey-Fuller (ADF) method confirm that all variables exhibit unit roots at their levels. Consequently, the variables need to be transformed to stationarity by differencing them to the first order.
The ADF results after first-order differences show p-values of 0.0001 for ΔLNCO2_cap\Delta LNCO2_cap, 0.0069 for ΔLNPBB_cap\Delta LNPBB_cap, and 0.001 for ΔREN\Delta REN, indicating stationarity after differencing. Furthermore, the Johansen Cointegration Test reveals no evidence of long-term relationships between the variables, suggesting that there is no need for an Error Correction Model (ECM). Instead, the Ordinary Least Squares (OLS) approach can be employed, with the analysis focusing on first-order differenced variables to ensure stationarity.

Table 4: Johansen Cointegration Test Results (Trace and Maximum Eigenvalue Statistics)

Series: LNCO2 CAP LNGDP CAP REN

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.447333	26.53773	29.79707	0.1134
At most 1	0.207863	9.340749	15.49471	0.3348
At most 2	0.085221	2.583126	3.841465	0.1080

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.447333	17.19698	21.13162	0.1629
At most 1	0.207863	6.757623	14.26460	0.5182
At most 2	0.085221	2.583126	3.841465	0.1080

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

The results indicate that the impact of GDP per capita on CO_2 emissions is not statistically significant, as the coefficient fails to meet significance thresholds. Despite this, the coefficient remains positive, suggesting that an increase in GDP per capita is associated with higher CO_2 emissions. This aligns with the general understanding that economic growth, particularly in developing economies, often correlates with increased energy consumption and emissions, albeit without substantial statistical support in this specific model.

On the other hand, the share of renewable energy emerges as a statistically significant variable in the model, confirming a negative relationship with CO_2 emissions. This implies that a higher proportion of renewable energy in the total energy mix leads to lower carbon emissions. Specifically, a 10-percentage-point increase in the share of renewable energy would reduce the growth rate of CO_2 emissions by approximately 0.13%. While this negative impact is statistically significant, its economic magnitude remains modest, suggesting that the current changes in renewable energy adoption may not yet have a profound effect on CO_2 reduction.

Table 5: Results of the Ordinary Least Squares (OLS) Regression Model for Changes in CO_2 Emissions

Dependent Variable: D(LNCO2_CAP)
Method: Least Squares

Sample (adjusted): 1991 2021
Included observations: 31 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNGDP_CAP)	0.306844	0.318914	0.962152	0.3442
D(REN)	-0.013185	0.002832	-4.656526	0.0001
C	0.003388	0.010879	0.311465	0.7578

R-squared	0.609873	Mean dependent var	0.001170
Adjusted R-squared	0.582007	S.D. dependent var	0.078348
S.E. of regression	0.050654	Akaike info criterion	-3.035828
Sum squared resid	0.071843	Schwarz criterion	-2.897055
Log likelihood	50.05534	Hannan-Quinn criter.	-2.990592
F-statistic	21.88576	Durbin-Watson stat	2.186396
Prob(F-statistic)	0.000002		

Specifically, the model explains approximately 61% of the variance in CO_2 emissions changes, as indicated by the R-squared value of 0.609873. Again the model explains approximately 61% of the variation in CO_2 emissions, with renewable energy being a significant contributor to this result. The adjusted R-squared, at 0.582007, further confirms the model's reliability in accounting for the variation in the dependent variable. The model is statistically significant overall, with an F-statistic p-value of 0.000002, well below the standard significance level of 0.05, indicating that the independent variables collectively contribute to explaining the variation in CO_2 emissions.

From a diagnostic perspective, the model exhibits no issues with heteroskedasticity, as evidenced by the Prob. Chi-Square value of 0.326, ensuring that the residuals have constant variance.

Table 6: Ramsey Reset Test

Ramsey RESET Test
Equation: UNTITLED
Omitted Variables: Powers of fitted values from 2 to 3
Specification: D(LNCO2_CAP) D(LNGDP_CAP) D(REN) C

	Value	df	Probability
F-statistic	2.465137	(2, 26)	0.1046
Likelihood ratio	5.382806	2	0.0678

Additionally, the Ramsey Reset Test confirms that the model is well-specified, meaning that there are no significant omitted variables or functional form misspecifications.

The Ramsey Reset test results indicate that the model does not suffer from specification errors. The F-statistic of 2.465137 and its associated p-value of 0.1046 are above the standard significance threshold (e.g., 0.05), meaning there is no significant evidence of omitted variables or functional form misspecifications. Similarly, the likelihood ratio test result, with a p-value of 0.0678, further supports this conclusion, as it does not reject the null hypothesis of correct model specification.

Table 7: LM test for serial correlation

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	0.915562	Prob. F(2,26)	0.4128
Obs*R-squared	2.039617	Prob. Chi-Square(2)	0.3607

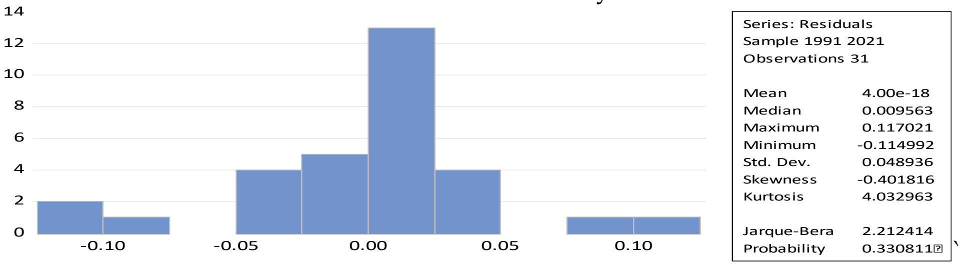
Additionally, the LM test for serial correlation confirms that the model is free from serial correlation issues, ensuring the independence of residuals across observations. Together, these results validate the appropriateness of the model for analyzing the relationship between changes in CO_2 emissions, GDP per capita, and renewable energy. The absence of major specification and diagnostic issues strengthens confidence in the reliability of the model's findings.

The robustness and reliability of the developed model are further reinforced by diagnostic tests on the residuals. The Breusch-Godfrey Serial Correlation LM test confirms the absence of serial correlation in the residuals, with p-values of 0.4128 (F-statistic) and 0.3607 (Chi-Square statistic) both exceeding the standard threshold of 0.05. This indicates that the residuals are independent across observations, fulfilling a key assumption of regression analysis.

Moreover, the normality of residuals is supported by the histogram and the Jarque-Bera test, which provides a p-value of 0.330811. This value exceeds the 0.05 significance threshold, allowing us to fail to reject the null hypothesis of normality. The descriptive statistics further support this conclusion, with a skewness of -0.4018 (close to zero) and a kurtosis of 4.032963 (slightly above the normal value of 3 but within an acceptable range). These results confirm that the residuals are symmetrically distributed around the mean and do not exhibit excessive tails, suggesting that the model satisfies the assumption of normally distributed errors.

Combining these results with the earlier findings, the model is well-specified, free from serial correlation, and meets the homoscedasticity and normality assumptions. This reinforces the conclusion that the model is robust and suitable for analyzing the relationship between changes in CO_2 emissions, GDP per capita, and renewable energy share in Albania. Furthermore, the negative relationship between renewable energy and CO_2 emissions, as well as the positive relationship between GDP and CO_2 emissions, are credible within the given economic and environmental context.

Table 8: Normality Test



3. Second Model

To validate the Environmental Kuznets Curve (EKC) hypothesis for the environment, the base model utilized is:
$CO_2 = β\_0 + β\_1 (En) + β\_2 (En^2) + β\_3 (X) + e$,
where \(CO2\) represents carbon dioxide emissions, \(En\) denotes the amount of fuel consumed, \(X\) includes other factors influencing CO_2 levels, and \(e\) represents the residuals. The data are presented in their logarithmic form. Variables in \(X\) include Trade Openness (exports + imports as a percentage of GDP), LNForest (forest area), LNPop (population size), and LNFDI (flows of foreign direct investment into the economy). The data span the period 1980–2023, except for \(En\) (1980–2014), FDI (1992–2023), and forest area (1990–2023).
Based on the study by Gumeni, Gorica, and Shalari, the results indicate no evidence of the EKC hypothesis for the environment in Albania. The model's results, as derived from their methodology, are presented but are unreliable due to the presence of unit roots in the variables. Consequently, the results in their current form cannot be considered valid. As the variables under analysis exhibit unit roots, it is necessary to transform them into their first differences for further examination.

Table 9 Model OLS

	1-st	2-nd	3-rd	4-th	5-th
LN_GDP	-6.16942	-123.291	-167.584	-132.851	20.30272
	0.0627	*0.1025*	*0.2511*	*0.3105*	*0.8902*
LN_GDP^2	1.221836	35.84246	49.02154	36.22557	-9.76558
	0.0158	*0.1078*	*0.2635*	*0.3483*	*0.8233*
LN_GDP^3		-3.40163	-4.73838	-3.22008	1.36863
		0.1199	*0.279*	*0.3955*	*0.7517*
LN_ENCon			1.328059	1.552777	1.104089
			0	*0*	*0.0066*

Ren					-0.00662
					0.0853
TradeOpenes			-0.0004	-374	0
			0.7304	*0.7022*	*0.9336*
LN_Forest				-24.1453	-22.3357
				0.3214	*0.3266*
LN_Pop			2.850122	18.6749	18.54496
			0.0041	*0.3392*	*0.3108*
Trend	-0.0311	-0.03292	-0.01492	0.020078	0.027546
	0	*0*	*0.0251*	*0.3995*	*0.2299*

The results of the ADF Unit Root Test reveal that most variables are non-stationary at their levels, with the exceptions of Trade Openness and Population, which are stationary without differencing. The remaining variables, including GDP, energy consumption, and renewable energy share, become stationary after differencing, primarily at the second order, except for forest area, which requires additional differencing.

Table 10: ADF Unit Root Test.

	LNCO2_ cap	LNPBB_ cap	REN	LN_ENCon	Trade Openes	LN_ Forest	LN_ Pop	LNFDI
Order 1	0.8963	0.3975	0.3871	0.8886	0.0122	0.1551	0.0501	0.4505
Order 2	0.0001	0.0069	0.001	0.0057		0.8833		0.0013
Order 3						0.0011		

Given these findings, it is necessary to evaluate whether the variables exhibit cointegration, which would indicate a long-term equilibrium relationship. If cointegration is present, the use of a Vector Error Correction Model (VECM) would be appropriate to analyze both short- and long-term dynamics. Conversely, in the absence of cointegration, a Vector Autoregressive (VAR) model with differenced variables would focus on short-term relationships.

The lag selection test indicates that, based on the Schwarz Information Criterion (SC), the optimal lag length for the model is three lags. This decision is supported by the SC value, which reaches its minimum at three lags (-12.74755). While other criteria, such as the Akaike Information Criterion (AIC) and Hannan-Quinn Criterion (HQ), suggest alternative lag lengths, the Schwarz criterion's tendency to select more parsimonious models aligns with the need for simplicity and interpretability in time-series modeling. Therefore, the model is constructed using three lags, ensuring that it captures the dynamic relationships among the variables effectively without overfitting.

Table 11: Lag Length Criteria Results

Included observations: 31

Lag	LogL	LR	FPE	AIC	SC	HQ
0	69.10482	NA	1.10e-08	-4.135795	-3.904506	-4.060400
1	234.8234	267.2880	1.29e-12	-13.21441	-11.82668	-12.76205
2	289.9169	71.08845	2.12e-13	-15.15593	-12.61176	-14.32659
3	334.9465	43.57701*	8.57e-14*	-16.44816	-12.74755*	-15.24185
4	368.7987	21.84016	1.21e-13	-17.01927*	-12.16222	-15.43599*

The Johansen Cointegration Test indicates the presence of cointegration among the variables, as the Trace Test identifies three cointegrating equations at the 5% significance level. Specifically, the null hypothesis of no cointegration is rejected, with the Trace Statistic (115.0260) exceeding the critical value (69.81889) and a p-value of 0.0000. Similarly, the hypothesis of at most one and at most two cointegrating equations is also rejected, confirming the existence of long-term equilibrium relationships among the variables.

Given these findings, the Vector Error Correction Model (VECM) is the appropriate approach to capture both the long-term cointegrating relationships and the short-term dynamics of the variables. This ensures that the model accounts for the equilibrium adjustments in the presence of deviations from the long-term relationships while also addressing short-term fluctuations in the data.

Table 12: The Johansen Cointegration Test

Lags interval (in first differences): 1 to 3

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.761661	115.0260	69.81889	0.0000
At most 1 *	0.724667	70.57013	47.85613	0.0001
At most 2 *	0.409068	30.58712	29.79707	0.0405
At most 3	0.322161	14.27946	15.49471	0.0756
At most 4	0.069266	2.225225	3.841465	0.1358

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

The normalized cointegration coefficient reveals a negative long-term relationship between GDP and CO_2 emissions, indicating that, over the long term, economic growth in Albania contributes positively to environmental outcomes. This suggests that Albania may have reached a stage where economic development is associated with improvements in environmental performance, aligning with the hypothesis that higher levels of income can lead to increased investment in cleaner technologies and sustainable practices.

The normalized cointegrating coefficients provide critical insights into the long-term relationships between the variables. The coefficient for energy consumption (LNENCON) is negative (-1.755488), indicating a positive long-term relationship between fuel consumption and CO_2 emissions. This suggests that increases in fuel consumption are strongly associated with higher levels of CO_2 emissions, as expected. Similarly, the coefficient for trade openness (TRADE) is also negative (-0.013355), highlighting a positive relationship between trade openness and CO_2 emissions, likely reflecting the environmental costs of increased trade activities.

Conversely, the coefficient for population (LNPOP) is positive (0.457626), suggesting that higher population levels are associated with reduced CO_2 emissions in the long run. However, this coefficient is not statistically significant, as indicated by its high standard error (1.08220), meaning this relationship should be interpreted with caution.

Table 13: The normalized cointegration coefficient

Normalized cointegrating coefficients (standard error in parentheses)

LNCO2_CAP	LNGDP_CAP	LNENCON	TRADE	LNPOP
1.000000	0.877950	-1.755488	-0.013355	0.457626
	(0.22749)	(0.49166)	(0.00270)	(1.08220)

The results of the Vector Error Correction Model (VECM) confirm the previously identified long-term relationships, offering further insights into the dynamics between CO_2 emissions, economic growth, energy consumption, trade openness, and population. Notably, GDP per capita (LNGDP_CAP) and population (LNPOP) are negatively associated with CO_2 emissions in the long run. These findings are counterintuitive, as these variables are generally expected to have positive coefficients, suggesting that higher economic activity and population growth typically lead to increased emissions. However, similar to previous higher levels of income, the negative relationship implies that Albania may have reached a stage where economic development and population growth are accompanied by improved environmental policies and practices, reflecting a transition toward sustainable development.

Energy consumption (LNENCON) also exhibits a negative coefficient, indicating a positive long-term association with CO_2 emissions. This aligns with expectations, as increased energy consumption typically results in higher emissions, reinforcing the importance of transitioning to renewable energy sources to mitigate environmental impacts. Meanwhile, trade openness (TRADE) does not display a significant long-term relationship with CO_2 emissions, suggesting that trade activities in Albania have not yet had a substantial environmental impact.

Cointegrating Eq:	CointEq1
LNCO2_CAP(-1)	1.000000
LNGDP_CAP(-1)	-0.227363 (0.06208) [-3.66269]
LNENCON(-1)	-1.568302 (0.13846) [-11.3265]
TRADE(-1)	0.000488 (0.00071) [0.69034]
LNPOP(-1)	-0.929098 (0.34815) [-2.66866]
C	8.043015

Table 14: VECM Long Term Results

Building on the findings of Ashraf and Hafeez-ur-Rehman (2023), which indicate that most developing countries remain on the upward-sloping segment of the Environmental Kuznets Curve due to low per capita income, this study's results suggest that Albania may represent a unique case among developing nations (According to the World Bank Classification 2024). The negative long-term association between GDP per capita and CO_2 emissions in Albania indicates a potential transition toward sustainable development, driven by enhanced environmental policies and practices. Perhaps it is time for researchers to consider Albania's position on the Kuznets Curve as distinctive, given that 98% of its energy resources come from renewable sources (hydropower and solar) and its Gross Domestic Energy Productivity (GAE) is 4.9 euros per kgoe (Eurostat, 2020, conclusions of 2022).

This perspective is further supported by Eurostat data, which show that Albania holds the second-highest energy productivity among EU candidate countries, according to the 2022 report, despite the most recent data being from 2020. This finding aligns with my research, which suggests that Albania, classified by the World Bank as an upper-middle-income country, is exhibiting trends similar to those observed in high-income countries. This phenomenon aligns with the descending phase of the Kuznets Curve, where economic growth leads to improved energy efficiency and a reduced environmental impact (Eurostat, 2022).

The short-term dynamics from the Vector Error Correction Model (VECM) reveal key insights into the immediate relationships between CO_2 emissions and the explanatory variables. Specifically, the lagged effects of CO_2 emissions indicate that a 1% increase in emissions one year prior is associated with a 0.31% increase in current emissions, while a 1% increase in emissions two years prior corresponds to a 0.38% rise in current emissions. However, these coefficients are not statistically significant, limiting their interpretative value.

In contrast, economic growth exhibits a significant short-term impact. A 1 percentage point increase in GDP growth two years prior is associated with a 2.03 percentage point reduction in the current growth rate of CO_2 emissions, significant at the 10% level. This finding aligns with the notion that economic development in Albania may increasingly reflect environmentally conscious practices, even in the short term.

Despite these individual findings, the overall model is not statistically significant, as indicated by the F-statistic p-value of 0.109623. This implies that the explanatory power of the model, when all variables are considered together, does not reach significance at the 10% level. Therefore, while certain individual relationships are noteworthy, the model as a whole lacks robustness in explaining the short-term variations in CO_2 emissions.

Table 15: Vector Error Correction Model (VECM) coefficients for the short-term Dynamics.

D(LNCO2_CAP) = C(1)*(LNCO2_CAP(-1) - 0.227363136449 *LNGDP_CAP(-1) - 1.56830214109*LNENCON(-1) + 0.000488222433759*TRADE(-1) - 0.929098061813*LNPOP(-1) + 8.04301492976) + C(2)*D(LNCO2_CAP(-1)) + C(3) *D(LNCO2_CAP(-2)) + C(4)*D(LNGDP_CAP(-1)) + C(5) *D(LNGDP_CAP(-2)) + C(6)*D(LNENCON(-1)) + C(7) *D(LNENCON(-2)) + C(8)*D(TRADE(-1)) + C(9)*D(TRADE(-2)) + C(10)*D(LNPOP(-1)) + C(11)*D(LNPOP(-2)) + C(12)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-1.394097	0.564092	-2.471400	0.0221
C(2)	0.312748	0.396093	0.789581	0.4386
C(3)	0.377409	0.328287	1.149632	0.2632
C(4)	-0.091612	0.758793	-0.120734	0.9050
C(5)	-2.031594	1.033538	-1.965669	0.0627
C(6)	-0.525204	0.822627	-0.638448	0.5301
C(7)	-0.358642	0.542586	-0.660986	0.5158
C(8)	-0.002296	0.001798	-1.276981	0.2155
C(9)	-0.000878	0.001039	-0.845741	0.4072
C(10)	14.55495	10.30911	1.411853	0.1726
C(11)	-16.34608	10.94667	-1.493248	0.1502
C(12)	0.023416	0.021809	1.073677	0.2952

R-squared	0.491437	Mean dependent var	-0.006223
Adjusted R-squared	0.225047	S.D. dependent var	0.085301
S.E. of regression	0.075091	Akaike info criterion	-2.064938
Sum squared resid	0.118413	Schwarz criterion	-1.520753
Log likelihood	46.07147	Hannan-Quinn criter.	-1.881836
F-statistic	1.844804	Durbin-Watson stat	1.870533
Prob(F-statistic)	0.109623		

Attempts to construct a system where GDP has an impact on CO_2 emissions included removing the variables for fuel consumption and trade openness together, and subsequently removing only trade openness. However, the results remain statistically insignificant and merely indicative. The indicative results in Model 2 suggest that the impact of GDP on CO_2 emissions is negative in the short term (indicative) and positive in the long term. This means that GDP growth in the short term is associated with an increase in CO_2 emissions, whereas in the long term, it is associated with a decrease in emissions. A similar pattern is observed for population, with indicative effects in both short and long-term cases.

For fuel consumption, the results indicate a decrease in emissions in the short term (indicative and not statistically significant) and an increase in the long term. Other variables considered, such as forest area and foreign direct investment levels, were included in the testing within Model 2, but they did not prove statistically significant, making it impossible to build a reliable econometric model with these variables. Even in a simplified model examining only GDP and CO_2 emissions, there is no evidence of long-term cointegration.

Together with the results from Model 1, these findings show no statistically clear form of GDP's impact on CO_2 emissions. However, indicative results suggest that GDP increases CO_2 emissions in the short term and reduces them in the long term. At the same time, fuel consumption increases emissions in the long term. From Model 1, it was also noted that the share of renewable energy is statistically significant in reducing CO_2 emissions.

Table 16: VECM in the short-term

Error Correction:	D(LNCO2 ...
CointEq1	-1.286423
	(0.55138)
	[-2.33310]
D(LNCO2 CAP(-1))	0.243595
	(0.38665)
	[0.63001]
D(LNCO2 CAP(-2))	0.416618
	(0.31930)
	[1.30480]
D(LNGDP CAP(-1))	-0.176870
	(0.73774)
	[-0.23975]
D(LNGDP CAP(-2))	-2.466391
	(1.04148)
	[-2.36817]
D(LNENCON(-1))	-0.332906
	(0.80735)
	[-0.41234]
D(LNENCON(-2))	-0.061696
	(0.56066)
	[-0.11004]
D(TRADE(-1))	-0.002760
	(0.00177)
	[-1.56005]
D(TRADE(-2))	-0.000862
	(0.00101)
	[-0.85609]
D(LNPOP(-1))	14.20666
	(9.99705)
	[1.42109]
D(LNPOP(-2))	-17.44482
	(10.6368)
	[-1.64004]
C	0.036066
	(0.02270)
	[1.58872]
R-squared	0.524794
Adj. R-squared	0.263431
Sum sq. resids	0.105995
S.E. equation	0.072799
F-statistic	2.007914
Log likelihood	45.95558
Akaike AIC	-2.122224
Schwarz SC	-1.572573
Mean dependent	-0.003178
S.D. dependent	0.084824

To further analyze the impact of the variables under consideration, an ECM model was constructed, excluding the VAR structure. The results indicate that among GDP per capita, fuel consumption, and foreign direct investments (FDI), only fuel consumption shows a statistically significant impact on CO_2 emissions. Specifically, the coefficient for fuel consumption (D(LNENCON)) is positive and statistically significant ($p<0.01$), indicating that an increase in fuel consumption is associated with a rise in CO_2 emissions.

In this model, the Error Correction Mechanism (ECM) term, which measures the speed of adjustment toward the long-term equilibrium, is also statistically significant ($p<0.01$) with a coefficient of -0.859191. *This suggests that approximately 86% of the disequilibrium from the previous period is corrected in the current period, indicating a relatively fast adjustment to the long-term relationship.*

The other variables, GDP per capita (D(LNGDP_CAP)) and FDI (D(LNFDI)), are not statistically significant in this model. Their coefficients indicate only indicative relationships with CO_2 emissions, with p-values exceeding the standard significance levels. The overall model demonstrates good explanatory power, with an R^2 of 0.734103 and an adjusted R^2 of 0.671539, indicating that the included variables explain a substantial portion of the variation in CO_2 emissions. However, the statistical significance of fuel consumption as the primary driver highlights its central role in influencing emissions levels in the context of this analysis.

Table 17: ECM Model

Included observations: 22 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNGDP CAP)	0.121225	0.493503	0.245642	0.8089
D(LNENCON)	1.322414	0.257109	5.143389	0.0001
D(LNFDI)	0.073443	0.056143	1.308155	0.2082
C	-0.005668	0.013029	-0.435001	0.6690
ECM(-1)	-0.859191	0.240718	-3.569286	0.0024

R-squared	0.734103	Mean dependent var	0.019452
Adjusted R-squared	0.671539	S.D. dependent var	0.067247
S.E. of regression	0.038540	Akaike info criterion	-3.477508
Sum squared resid	0.025251	Schwarz criterion	-3.229544
Log likelihood	43.25259	Hannan-Quinn criter.	-3.419095
F-statistic	11.73366	Durbin-Watson stat	1.997198
Prob(F-statistic)	0.000093		

The Granger Causality Test Results reveal several significant relationships among the variables under study, highlighting potential causal dynamics in the economic and environmental context. Specifically, economic growth is found to Granger-cause changes in energy consumption (p = 0.0030), suggesting that as an economy expands, it influences energy usage patterns, likely due to increased industrial activity and consumer demand. Additionally, changes in foreign direct investment (FDI) Granger-cause changes in CO_2 emissions per capita (p = 0.0330), indicating that FDI inflows might contribute to shifts in carbon emissions, potentially through technology transfer or industrial development. Another noteworthy finding is that energy consumption Granger-causes changes in GDP per capita (p = 0.0033), reflecting the fundamental role of energy as a driver of economic output and productivity. Lastly, changes in FDI also Granger-cause shifts in renewable energy use (p = 0.0168), suggesting that foreign investments may foster the adoption of renewable energy technologies or infrastructure development.

Table 18: The Granger causality test

Null Hypothesis:	Obs	F-Statistic	Prob.
D(LNCO2_CAP) does not Granger Cause GROWTH	41	0.46897	0.6294
GROWTH does not Granger Cause D(LNCO2_CAP)		1.47140	0.2431
D(LNENCON) does not Granger Cause GROWTH	32	0.75574	0.4793
GROWTH does not Granger Cause D(LNENCON)		6.79423	0.0041
D(LNGDP_CAP) does not Granger Cause GROWTH	41	0.60329	0.5524
GROWTH does not Granger Cause D(LNGDP_CAP)		0.42692	0.6558
D(LNFDI) does not Granger Cause GROWTH	29	0.06476	0.9375
GROWTH does not Granger Cause D(LNFDI)		2.00806	0.1562
D(REN) does not Granger Cause GROWTH	29	0.31955	0.7295
GROWTH does not Granger Cause D(REN)		1.78076	0.1901
D(LNENCON) does not Granger Cause D(LNCO2_CAP)	32	1.83752	0.1786
D(LNCO2_CAP) does not Granger Cause D(LNENCON)		1.56512	0.2274
D(LNGDP_CAP) does not Granger Cause D(LNCO2_CAP)	41	1.83698	0.1739
D(LNCO2_CAP) does not Granger Cause D(LNGDP_CAP)		0.70724	0.4997
D(LNFDI) does not Granger Cause D(LNCO2_CAP)	29	0.47568	0.6272
D(LNCO2_CAP) does not Granger Cause D(LNFDI)		3.94505	0.0330
D(REN) does not Granger Cause D(LNCO2_CAP)	29	1.52738	0.2375
D(LNCO2_CAP) does not Granger Cause D(REN)		0.04721	0.9540
D(LNGDP_CAP) does not Granger Cause D(LNENCON)	32	7.11351	0.0033
D(LNENCON) does not Granger Cause D(LNGDP_CAP)		0.83310	0.4456
D(LNFDI) does not Granger Cause D(LNENCON)	20	0.42818	0.6594
D(LNENCON) does not Granger Cause D(LNFDI)		3.28110	0.0658
D(REN) does not Granger Cause D(LNENCON)	22	1.45969	0.2600
D(LNENCON) does not Granger Cause D(REN)		1.86262	0.1856
D(LNFDI) does not Granger Cause D(LNGDP_CAP)	29	0.04241	0.9585
D(LNGDP_CAP) does not Granger Cause D(LNFDI)		2.09746	0.1447
D(REN) does not Granger Cause D(LNGDP_CAP)	29	0.44160	0.6481
D(LNGDP_CAP) does not Granger Cause D(REN)		1.94036	0.1655
D(REN) does not Granger Cause D(LNFDI)	27	4.94495	0.0168
D(LNFDI) does not Granger Cause D(REN)		0.20670	0.8148

4. Model and Methodology

This paper utilizes a combination of econometric models, including Ordinary Least Squares (OLS), Vector Error Correction Model (VECM), and Error Correction Mechanism (ECM), to examine the relationship between economic growth and environmental sustainability in Albania, with a specific focus on the Environmental Kuznets Curve (EKC). The models incorporate key variables such as GDP per capita, energy consumption, trade openness, population, foreign direct investment (FDI), and renewable energy to analyze the short- and long-term dynamics of CO_2 emissions. The study employs stationarity and cointegration tests to ensure robustness, finding evidence of cointegration among key variables, justifying the application of the VECM framework. Additionally, the ECM analysis reveals a significant adjustment mechanism toward long-term equilibrium, particularly for the impact of fuel consumption on emissions. The paper integrates findings from Albanian and global contexts, supported by robust econometric methodologies such as cointegration and error correction models, ensuring both academic rigor and policy relevance.

4.1 Model Specification

This study investigates the determinants of carbon dioxide (CO_2) emissions in Albania by employing a suite of econometric models, including Ordinary Least Squares (OLS), Vector Error Correction Model (VECM), and Error Correction Mechanism (ECM), utilizing time-series data spanning from 1990 to 2023. The dependent variable is CO_2 emissions per capita, while the independent variables include Gross Domestic Product (GDP) per capita, the squared and cubic terms of GDP to test for the Environmental Kuznets Curve (EKC) hypothesis, energy consumption (proxied by fuel usage), trade openness, population, and foreign direct investment (FDI).

The inclusion of both linear and nonlinear terms of GDP enables the study to test the EKC hypothesis, which posits an inverted U-shaped relationship between economic growth and environmental degradation. The analysis extends beyond a static OLS framework by incorporating cointegration techniques to capture both short- and long-term dynamics. Stationarity of the data is ensured through the Augmented Dickey-Fuller (ADF) test, and the Johansen Cointegration Test confirms the presence of long-term equilibrium relationships among the variables, justifying the use of a VECM.

Data for this study were sourced from reputable institutions, including the World Bank and the International Energy Agency, ensuring reliability and consistency in the variables analyzed.

5. Results

The results indicate that the relationship between GDP and CO_2 emissions is complex and time-dependent. In the short term, GDP growth appears to have an indicative positive impact on CO_2 emissions, reflecting increased economic activity and energy consumption. However, in the long term, the relationship turns negative, suggesting that Albania may be transitioning toward more sustainable practices, aligning partially with the Environmental Kuznets Curve (EKC) hypothesis.

The results suggest also that Albania, as an upper-middle-income country, may represent a unique case among developing nations, aligning with the descending phase of the Environmental Kuznets Curve, where economic growth improves energy efficiency and reduces environmental impact (Ashraf and Hafeez-ur-Rehman, 2023).

Fuel consumption emerges as the most statistically significant determinant of CO_2 emissions, demonstrating a strong positive relationship in both short- and long-term analyses, highlighting its critical role in driving environmental impact. Conversely, renewable energy shows a statistically significant negative impact on emissions, underscoring its importance in reducing Albania's carbon footprint and mitigating environmental degradation.

The relationship between GDP and CO_2 emissions is complex and time-dependent, with indicative findings suggesting that economic growth may increase emissions in the short term but potentially decrease them in the long term, aligning with the hypothesized trajectory of the EKC. I developed another non-linear regression model to analyze threshold effects for renewable energy; however, the results indicated the presence of unit roots. Consequently, it was not possible to identify a maximum investment limit in renewable energy to determine where CO_2 emissions might begin to overlap or decrease. Other variables, such as trade openness, foreign direct investment (FDI), and population, do not exhibit statistically significant effects within the current modeling framework, although their indicative results suggest potential areas for further exploration.-

Renewable energy, when included, is statistically significant in reducing CO_2 emissions. While GDP shows indicative results, its relationship with emissions varies over time, with a potential short-term increase in emissions followed by long-term reductions, aligning partially with the EKC hypothesis. Trade openness and population exhibit statistically insignificant effects in the current models, highlighting the need for further refinement and exploration of these relationships.

The results emphasize the need for targeted interventions, such as increasing renewable energy adoption, improving energy efficiency, enhancing value-added production through investments in technology, scientific research, and education, to balance economic growth with environmental preservation. These measures aim to align Albania's trajectory with successful examples like South Korea and Costa Rica, while providing valuable lessons to avoid environmentally detrimental pathways observed in countries like Brazil and India.

6. Limitations

The analysis faces several limitations that should be considered when interpreting the findings. First, while the models incorporate nonlinear terms to test the Environmental Kuznets Curve (EKC) hypothesis, the relationships explored remain subject to the simplifying assumption of stationarity and econometric stability, which may not fully capture dynamic changes over time. Additionally, the models rely on historical data from 1990 to 2023, which may not adequately reflect the effects of recent or future policy interventions, technological advancements, or global economic shocks, such as shifts in energy markets or environmental policies.

Moreover, key variables like trade openness, foreign direct investment (FDI), and population were found to be statistically insignificant in the current framework, potentially due to data limitations, model specification issues, or insufficient variability within the dataset. The role of renewable energy, although significant in reducing emissions, could not be deeply analyzed in combination with other structural variables, limiting insights into its broader interactions with economic activity.

Finally, the results are indicative in many cases, particularly regarding GDP's short- and long-term impacts on CO_2 emissions, which remain inconsistent and context-dependent.

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