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Investigating CO2 Emissions Drivers: Energy Use, Economic Growth, Urbanization, and Trade Openness

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Abstract
This article investigates the impact of energy consumption, economic growth, urbanization, and trade openness on carbon dioxide emissions for a global panel comprising 58 countries. Utilizing dynamic simultaneous-equation panel data models, we analyze three regional panels: European and North Asian countries, Latin America and the Caribbean, and the Middle East, North Africa, and sub-Saharan regions. The dataset spans from 1990 to 2021, providing a comprehensive temporal scope for analysis. Our results reveal that energy consumption has a statistically significant positive effect on CO2 emissions across all four panels. This finding underscores the direct correlation between higher energy usage and increased carbon emissions, highlighting the environmental cost of energy consumption. Similarly, GDP per capita exhibits a positive and statistically significant effect on CO2 emissions for the global panel, as well as specifically for European and North Asian countries, and the Middle East, North Africa, and sub-Saharan regions. This indicates that economic growth, as measured by GDP per capita, contributes to higher CO2 emissions, reflecting the environmental implications of economic expansion. Interestingly, our empirical results also suggest the presence of an inverted U-shaped curve, known as the Environmental Kuznets Curve (EKC), between CO2 emissions and GDP per capita. This implies that initially, economic growth leads to increased emissions; however, after reaching a certain income level, further economic growth results in reduced emissions. This pattern suggests that economic development eventually facilitates investments in cleaner technologies and more stringent environmental regulations. Urbanization, on the other hand, is found to have a negative and statistically significant impact on CO2 emissions for the global panel. This result indicates that increased urbanization may lead to more efficient energy use and lower per capita emissions, possibly due to better infrastructure and public transportation systems prevalent in urban areas. Trade openness presents a nuanced picture. For the European and North Asian countries, as well as the Middle East, North Africa, and sub-Saharan regions, trade openness has a negative and statistically significant effect on CO2 emissions. This suggests that greater integration into the global economy may encourage the adoption of cleaner technologies and more stringent environmental standards, thereby reducing emissions. Conversely, the impact of trade openness on CO2 emissions in Latin America and the Caribbean was not statistically significant in our analysis. Overall, this study provides valuable insights into the complex interactions between energy consumption, economic growth, urbanization, trade openness, and CO2 emissions. The findings suggest that while economic growth and energy consumption are major drivers of CO2 emissions, urbanization and trade openness can potentially mitigate these effects. Policymakers can leverage these insights to design strategies that balance economic development with environmental sustainability. Emphasizing energy efficiency, supporting urban infrastructure development, and fostering international trade relations that prioritize environmental standards are crucial steps toward reducing global carbon emissions.
Keywords: CO2 Emissions, Energy Consumption, Economic Growth
JEL Codes: Q53, Q56, O44

1. INTRODUCTION
The relationship between economic growth and environmental pollution has been a significant focus in ecological economic literature. Recent research has particularly emphasized the interaction between economic growth, energy consumption, and environmental impact. Scholars such as Copeland and Taylor (2004), Ang (2007), and Apergis and Payne (2009) have explored this relationship, integrating insights from both the Environmental Kuznets Curve (EKC) and the energy consumption-growth literature. The EKC hypothesis posits a relationship where emissions initially rise with income growth until a certain income threshold is reached. Beyond this threshold, emissions are expected to decline as economic development progresses (Grossman and Krueger, 1995). This framework provides a theoretical lens to understand how economic activities, energy consumption patterns, and environmental outcomes intersect over different stages of economic development. The Environmental Kuznets Curve (EKC), which suggests an inverted U-shaped relationship between environmental quality and per capita income, has been a subject of empirical testing in various studies. Stern (2004) and researchers like Coondoo and Dinda (2002), Luzzati and Orsini (2009), and Halicioglu (2009) have conducted extensive examinations of the economic growth-environmental pollution nexus within the framework of the EKC hypothesis. These studies investigate how environmental indicators such as pollution levels change with economic development. They explore whether initially, economic growth leads to increased pollution, but

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beyond a certain income threshold, further economic growth begins to mitigate environmental degradation. Such research contributes to understanding the complex relationship between economic prosperity, energy consumption patterns, and environmental sustainability.

The relationship between economic growth, energy consumption, and CO2 emissions has indeed been a significant focus in research, reflecting concerns over global fossil fuel consumption and its environmental impacts. Scholars such as Lise (2006), Squalli (2007), Soytas et al. (2007), Ang (2008), Akbostanci and Turut-Asik (2009), Apergis and Payne (2010), Soytas and Sari (2009), Lean and Smyth (2009), Zhang and Cheng (2009), Menyah and Wolde-Rufael (2010), Freitas and Kaneko (2011), and Narayan and Popp (2012) have contributed extensively to this area of study. Their research explores how increases in economic activity, driven by energy consumption predominantly from fossil fuels, correlate with rising CO2 emissions. This empirical inquiry has policy implications for balancing economic development with environmental sustainability, emphasizing the need for energy efficiency measures, renewable energy adoption, and environmental policies to mitigate CO2 emissions and climate change impacts. Our study aims to explore how economic growth and energy consumption influence CO2 emissions across a panel of 58 countries from 1990 to 2012. To achieve this, we utilized a dynamic panel data model, aligned with the conventional framework of growth models. This approach allows us to analyze the complex relationships between economic growth, energy consumption, and their impact on CO2 emissions comprehensively.

2. LITERATURE REVIEW

This section of the study focuses on reviewing the existing literature concerning the impact of energy consumption, economic growth, urbanization, and trade openness on CO2 emissions. This review encompasses both theoretical frameworks and empirical findings. Examining existing literature is crucial for gaining a comprehensive understanding of current knowledge in the field. Table 1 provides a summary of empirical studies investigating the effects of energy consumption and economic growth on CO2 emissions. Therefore, this paper organizes the literature review into three subsections: (a) the influence of GDP on CO2 emissions, (b) the impact of energy on CO2 emissions, and (c) the effects of urbanization and trade openness. Each subsection is discussed in detail below. The literature review reveals that many studies primarily investigate the relationship between economic output and environmental pollution. For instance, Perman and Stern (2003) utilized a panel co-integration approach to explore the Environmental Kuznets Curve (EKC) hypothesis across a panel of 74 countries spanning from 1850 to 1990. Their findings indicate that both per capita income and its squared term positively and significantly affect CO2 emissions, with no supportive evidence found for the EKC hypothesis. Similarly, Markandya et al. (2006) analyzed the connection between per capita GDP and sulfur dioxide (SO2) emissions across 12 Western European countries. Richmond and Kaufmann (2006) found an inverted U-shaped relationship between income and pollution, suggesting that air pollution regulations affect the pattern of income and pollution relationship. Managi (2006) argued that economic growth and decreasing environmental degradation can align with the Environmental Kuznets Curve (EKC) hypothesis. This hypothesis posits that as economies develop, they initially experience increased pollution levels followed by a decline after reaching a certain income threshold, reflecting an inverted U-shaped relationship between economic performance and environmental pollution.

Soytas et al. (2007) investigated the impact of energy consumption and output on carbon emissions in the United States from 1960 to 2004, using Granger causality analysis that incorporated labor and gross fixed capital formation in their model. They concluded that income does not Granger cause carbon emissions in the US over the long run, indicating that economic growth alone may not effectively address environmental concerns. Similar findings were observed in Turkey by Soytas and Sari (2009), where no long-run Granger causality was found between income and carbon emissions, suggesting that both countries are managing to reduce carbon emissions without sacrificing economic growth. Additionally, Halicioglu (2009) highlighted that income exerts a more significant impact on CO2 emissions in Turkey compared to energy consumption. Narayan and Narayan (2010) examined the Environmental Kuznets Curve (EKC) hypothesis for 43 developing countries, emphasizing the challenges in testing the relationship between emissions and income over both the short and long run, particularly concerning issues such as collinearity between income and income squared, which are commonly used in EKC model specifications.

The relationship between CO2 emissions and economic growth, alongside their association with energy consumption, has attracted significant scholarly attention in recent years. For example, Soytas et al. (2007) and Soytas and Sari (2009) identified a positive correlation between energy consumption and pollution emissions in the United States and Turkey, respectively. Ang (2008) underscored the direct influence of energy consumption on environmental pollution, highlighting the critical interconnections between these domains. Lean and Smyth (2009) explored the nexus of electricity consumption, CO2 emissions, and economic output across ASEAN countries, revealing a substantial long-term relationship between electricity use and emissions. Apergis and Payne (2010) expanded this analysis to Central American nations, concluding that while energy consumption exerts a positive long-term influence on CO2 emissions, real output conforms to the Environmental Kuznets Curve (EKC) hypothesis. Halicioglu (2009) investigated Turkey's dynamics, uncovering that CO2 emissions are shaped by energy consumption, GDP, and foreign trade over the long term, emphasizing the diverse determinants of environmental impacts across different economic contexts.

The impact of energy consumption on carbon dioxide (CO2) emissions and its interaction with economic growth has been extensively explored across various regions. For instance, Arouri et al. (2012) studied 12 Middle Eastern and North African countries from 1981 to 2005, revealing a significant positive long-run relationship between energy consumption and CO2 emissions. They also highlighted a quadratic relationship between real GDP and CO2 emissions in the MENA region, indicating a nuanced economic impact on environmental outcomes. In another study, Boopen and

Harris (2012) focused on Mauritius spanning from 1960 to 2011. They found that energy consumption exerts a significant influence on CO_2 emissions, while controlling for trade, capital, and labor variables. Their analysis, which included co-integration and non-stationarity tests, underscored the interconnected nature of energy usage, economic growth, and emissions in small island economies. Yang et al. (2012) focused their study on Shanghai from 2011 to 2020, employing co-integration and vector error correction models to explore the causal relationships among carbon emissions, energy consumption, and economic growth. They concluded that in the long-run equilibrium, there exists a positive association between carbon emissions and energy consumption. This finding reflects the complex interplay between urban development, industrialization, and environmental sustainability in a rapidly growing city. Trade openness, which encompasses scale, technique, and composition effects, has been a subject of significant debate in environmental economics. Antweiler (2001) discussed the complexities of how free trade impacts the environment, highlighting both positive and negative implications. Ferrantino (1997) and Grether et al. (2007) found evidence suggesting that trade can have beneficial effects on the environment. Conversely, others such as Suri (1998) and Abler et al. (1999) raised concerns about potential detrimental effects, especially in pollution-intensive industries. Urbanization's impact on carbon dioxide (CO_2) emissions has been a subject of extensive study in recent years. Fan et al. (2006) employed the STIRPAT model to analyze the factors influencing CO_2 emissions, revealing a complex relationship between urban development and environmental impacts. Dhakal (2009) focused on China, emphasizing the significant contribution of urban energy use to CO_2 emissions and highlighting policy implications for sustainable urban development. Similarly, Jalil and Mahmud (2009) investigated the Environmental Kuznets Curve for CO_2 emissions in China, identifying income and energy consumption as pivotal factors shaping long-term emission trends. These studies underscore the intricate dynamics of urbanization and its implications for environmental sustainability.

Urbanization's influence on carbon dioxide (CO_2) emissions has been explored by Liddle and Lung (2010), who examined age-structure and consumption-related environmental impacts across developing countries. Their study revisited the STIRPAT model to elucidate urbanization dynamics within the framework of climate change. These investigations collectively underscore the complex relationships between economic activities, urban development, trade openness, and environmental outcomes. They emphasize the necessity for targeted policy interventions aimed at fostering sustainable development on a global scale. Specifically, urbanization has been found to exert a positive and statistically significant impact on carbon dioxide emissions, particularly when considering emissions from transport as a dependent variable. Poumanyvong and Kaneko (2010) analyzed the impact of urbanization on CO_2 emissions, finding that urbanization generally results in higher CO_2 emissions across all income groups, with a more pronounced effect observed in intermediary income countries compared to others.

Sharma (2011) concluded that trade has a negative effect on CO_2 emissions, suggesting that trade may play a role in reducing emissions through mechanisms such as technological diffusion or efficiency gains. Martínez-Zarzoso and Maruotti (2011) focused on developing countries, examining the specific impact of urbanization on CO_2 emissions. Their study provided valuable insights into how urban development influences environmental outcomes in these regions. The findings revealed an inverted-U shaped relationship between urbanization and CO_2 emissions. Initially, the elasticity of emissions with respect to urbanization was positive at low urbanization levels, reflecting higher environmental impacts in less developed regions. However, for two of the groups studied, a threshold level was identified beyond which the elasticity turned negative. This suggests that further increases in urbanization rates beyond this threshold do not lead to higher emissions. The differential impact of urbanization on CO_2 emissions underscores the need to consider these nuances in future discussions on climate change policies.

The findings of Hossain (2011) revealed a long-run co-integrating vector among CO_2 emissions, output, energy consumption, trade openness, and urbanization across 9 newly industrialized countries over the period 1971 to 2007. In this context, a 1% increase in energy use was associated with a 1.2% increase in CO_2 emissions, while urbanization was found to lower CO_2 emissions by 0.6%. Similarly, Sharma (2011) analyzed a panel of 69 countries over the period 1985-2005 and found that urbanization has a negative and statistically significant impact on carbon emissions for the global panel. Specifically, a 1% increase in urbanization was linked to a decrease of CO_2 emissions by 0.7%. However, urbanization showed a negative but statistically insignificant impact on carbon emissions in panels representing low-income, middle-income, and high-income countries (Sadorsky, 2014). It's noteworthy that most studies, including Sulaiman et al. (2013), have investigated the impact of electricity generation from renewable sources on the environment and trade openness in Malaysia from 1980 to 2009. Using the Autoregressive Distributed Lag (ARDL) approach, these studies concluded that trade openness has a significant negative effect on CO_2 emissions in the long run (Sulaiman et al., 2013).

3. METHODOLOGY

The objective of this study is to explore the influence of energy consumption (ENRC), economic growth (GDP), squared GDP (GDP2), trade openness (TR), and urbanization (URB) on CO_2 emissions. Previous research by Ang (2008), Halicioglu (2009), and Hossain (2011), among others, has incorporated energy consumption and economic growth variables into their models to investigate their impact on CO_2 emissions. These studies generally conclude that energy consumption and economic growth positively affect CO_2 emissions, highlighting their significant roles in emissions dynamics. Additionally, studies by Hossain (2011) and Saboori (2012) have indicated that urbanization and trade openness exert negative and positive effects on CO_2 emissions, respectively. Hence, our proposed model aligns with these findings from the broader literature on CO_2 emission determinants, incorporating these variables to comprehensively examine their relationships.

$CO_2 = f$ (GDP, GDP^2, ENRC, URB, TR)
Where CO_2 is an environmental indicator function of economic growth (GDP), GDP^2 the GDP square per capita, Energy consumption per capita (ENRC), Trade openness (TR), and Urbanization (URB).
All the data were collected from the World Development Indicator. The study covers the period between 1990 and 2021 on 58 selected countries.

4. RESULTS AND DISCUSSIONS

Table 1 presents the results from a regression analysis where the dependent variable is per capita CO2 emissions. Here's the detailed interpretation of each coefficient. The coefficient for CO2 t-1 is -0.00049 with a p-value of 0.000, indicating strong statistical significance. This suggests that past levels of CO2 emissions per capita have a negative effect on current emissions, implying persistence in carbon emissions over time. For GDP per capita, the coefficient is 1.912 with a p-value of 0.000, indicating high statistical significance. This positive coefficient indicates that higher GDP per capita is associated with increased per capita CO2 emissions, reflecting the well-documented positive relationship between economic development and carbon emissions. The coefficient for GDP square is 0.927 with a p-value of 0.000, showing statistical significance. This suggests a non-linear relationship between GDP per capita and CO2 emissions, specifically a U-shaped curve where emissions initially rise with GDP per capita but at a decreasing rate as GDP per capita further increases. ENRC per capita has a coefficient of 0.843 with a p-value of 0.000, indicating statistical significance. This implies that higher energy consumption per capita correlates positively with higher per capita CO2 emissions, highlighting the role of energy usage in contributing to carbon emissions. Urbanization (URB) shows a coefficient of -0.024 with a p-value of 0.093, slightly above the conventional significance level of 0.05. This suggests a weak negative association between urbanization and per capita CO2 emissions, though the statistical significance is marginal. Regarding Trade (TR), the coefficient is -0.0046 with a p-value of 0.143, indicating that trade openness does not have a statistically significant impact on per capita CO2 emissions in this regression model. The constant (C) term is 2.361 with a p-value of 0.010, indicating statistical significance. This represents the baseline level of per capita CO2 emissions when all independent variables are zero or at their average levels. In summary, based on Table 1's results, past CO2 emissions, GDP per capita, energy consumption per capita, and the quadratic effect of GDP per capita significantly influence per capita CO2 emissions. Urbanization shows a marginal negative impact, while trade openness does not significantly affect CO2 emissions per capita in this particular regression analysis.

Table 1: Result for whole sample

Dependent variable: per capita CO_2 emissions	Coefficient	P-Value
$CO_{2\ t-1}$	-0.00049*	0.000
GDP per capita	1.912*	0.000
GDP square	0.927*	0.000
ENRC per capita	0.843*	0.000
URB	-0.024***	0.093
TR	-0.0046	0.143
C	2.361	0.010

Table 2 presents the regression results for different sub-samples categorized by regions, focusing on the relationship between per capita CO2 emissions and various explanatory variables. The coefficient for CO2t-1 is 0.0029 with a significant p-value of 0.000, indicating a positive effect of past CO2 emissions on current emissions. GDP per capita shows a coefficient of 2.138 with a p-value of 0.005, suggesting a significant positive relationship with CO2 emissions. The quadratic term GDP square has a coefficient of -0.995 (p = 0.008), indicating a negative quadratic relationship with CO2 emissions. Energy consumption per capita (ENRC per capita) has a coefficient of 0.993 (p = 0.000), showing a significant positive association with CO2 emissions. Urbanization (URB) and trade openness (TR) show coefficients of -0.0079 (p = 0.622) and -0.0011 (p = 0.079), respectively, indicating no statistically significant relationship with CO2 emissions. The constant term is 0.085 with a p-value of 0.945, suggesting no statistical significance in the baseline level of CO2 emissions. Here, CO2t-1 has a coefficient of -0.041 with a p-value of 0.136, indicating no statistically significant relationship with past emissions affecting current emissions. GDP per capita shows a coefficient of -59.329 (p = 0.085), suggesting a negative relationship with CO2 emissions, though marginally significant. GDP square shows a coefficient of 28.823 (p = 0.084), indicating a positive quadratic relationship with CO2 emissions, but not statistically significant. ENRC per capita has a coefficient of 0.744 (p = 0.000), showing a significant positive association with CO2 emissions. Urbanization (URB) and trade openness (TR) show coefficients of 0.819 (p = 0.142) and -0.096 (p = 0.420), respectively, indicating no statistically significant relationship with CO2 emissions. The constant term is -44.319 with a p-value of 0.162, suggesting no statistical significance in the baseline level of CO2 emissions. For this region, CO2t-1 has a coefficient of -0.0088 with a significant p-value of 0.000, indicating a negative effect of past CO2 emissions on current emissions. GDP per capita shows a coefficient of 23.132 (p = 0.053), suggesting a positive relationship with CO2 emissions, though not statistically significant. GDP square shows a coefficient of -11.586 (p = 0.054), indicating a negative quadratic relationship with CO2 emissions, though not statistically significant. ENRC per capita has a coefficient of 0.788 (p = 0.000), showing a significant positive association with CO2 emissions. Urbanization (URB) and trade openness (TR) show coefficients of 0.0017 (p = 0.960) and -0.051 (p = 0.056), respectively, indicating no statistically significant relationship with CO2 emissions. The constant term is 6.072 with a p-value of 0.056, indicating statistical significance in the baseline level of CO2 emissions. The Sargan test, used to test the validity of instruments, shows p-values of 0.254 for Europe and North Asia, 0.343 for Latin America and Caribbean, and 0.051 for Middle East, North Africa, and sub-Sahara. These values suggest that instruments used in the regressions are valid for Europe and North Asia and Latin America and Caribbean, while there may be issues for Middle East, North Africa, and sub-Sahara. The AR(2) test for autocorrelation in the errors shows p-values of 0.071, 0.354, and 0.761 for Europe and North Asia, Latin America and Caribbean, and Middle East, North Africa, and sub-Sahara, respectively, indicating possible autocorrelation issues in the first two regions but not in the latter.

Table 2: Estimation results for the Sub-Samples

	Dependent variable: per capita CO_2 emissions					
Variables	Europe and North Asia		Latin America and Caribbean		Middle East, North Africa, and sub-Sahara	
	Coefficient	P-Value	Coefficient	P-Value	Coefficient	P-Value
CO_{2t-1}	0.0029*	0.000	-0.041	0.136	-0.0088*	0.000
GDP per capita	2.138**	0.005	-59.329***	0.085	23.132***	0.053
GDP square	-0.995**	0.008	28.823***	0.084	-11.586***	0.054
ENRC per capita	0.993*	0.000	0.744*	0.000	0.788*	0.000
URB	-0.0079	0.622	0.819	0.142	0.0017	0.960
TR	-0.0011***	0.079	-0.096	0.420	-0.051***	0.056
Constants	0.085	0.945	-44.319	0.162	6.072***	0.056
Sargan test (p-value)	72.12	0.254	69.01	0.343	59.24***	0.051
AR(2) (p-value)	1.81***	0.071	-0.93	0.354	0.30	0.761

We found that the effect of economic growth on the CO_2 emissions is positive only for the global panel, Europe and North Asia, and the Middle East, North Africa, and the sub-Saharan, and statistically significant in the four panels. Likewise, it is found that the square GDP has a positive effect on the CO_2 emissions and statistically significant only for the global panel and for the Latin American and Caribbean panel. Further, the square GDP has a negative effect and statistically significant only for the Europe and North Asia, and the Middle East, North Africa, and the sub-Saharan. Second, energy consumption have a positive effect and statistically significant on the CO_2 emissions in the four panels. This indicates that an increase in energy consumption tends to increase CO2 emissions. Our results are different from the findings of Halicioglu (2009) and Iwata et al. (2010). Similarly, urbanization has a negative effect and is statistically significant on CO2 emissions for the global panel, but the coefficient is positive and not significant for the Middle Eastern, North African, and sub-Saharan panel, as well as for the Latin American and Caribbean panel.

5. CONCLUSIONS

The increasing global concern over rising carbon dioxide emissions has led to various policy responses aimed at curbing environmental impacts. Researchers have proposed several strategies to reduce these emissions, emphasizing the importance of understanding the factors influencing them. This study contributes to this understanding by empirically analyzing the roles of energy consumption, economic growth, urbanization, and trade openness in shaping CO2 emissions. Utilizing dynamic panel data models with simultaneous-equations, the research investigates a comprehensive global panel comprising 58 countries spanning from 1990 to 2021. This approach allows for a nuanced examination of how these variables interact over time, offering insights that can inform effective environmental policy-making on a global scale. The study yields significant findings regarding the relationship between key variables and CO2 emissions across different panels of countries. Firstly, it is observed that energy consumption per capita exerts a consistently positive effect on carbon emissions across all panels. Given this linkage, the study recommends policymakers consider shifting towards renewable energy sources to mitigate the environmental impact associated with fossil fuel use in both consumption and production. Secondly, the study examines the relationship between economic growth (measured by GDP per capita) and CO2 emissions using both linear and non-linear terms. The findings support the existence of a U-shaped relationship, where an increase in GDP per capita initially leads to higher carbon emissions per capita. However, the negative coefficient of the squared term indicates a potential decoupling of CO2 emissions from GDP at higher income levels. This finding supports the Environmental Kuznets Curve (EKC) hypothesis, suggesting that as economies mature, they may achieve lower carbon intensity despite continued economic growth. Lastly, the study explores the impacts of trade openness and urbanization on CO2 emissions. It finds that trade openness has a negative effect on CO2 emissions specifically for Europe and North Asia, indicating that international trade may facilitate emission-reducing activities or the adoption of cleaner technologies in these regions. Additionally, urbanization shows a negative impact on CO2 emissions across the global panel, suggesting that urban development may be associated with environmental policies or technological advancements that reduce carbon emissions. These results underscore the complexity of factors influencing CO2 emissions and emphasize the importance of tailored policies that consider the interplay between energy consumption, economic development, trade dynamics, and urbanization in achieving sustainable environmental outcomes globally. Based on the findings of this study, it can be concluded that there is a positive relationship between CO2 emissions and energy consumption. Future research could expand upon this by exploring additional variables such as economic growth, energy consumption, and their impact on pollution emissions, as well as considering factors like automobile usage, health expenditure, and financial development. Narayan and Narayan (2010) have already incorporated financial development into their analysis of energy consumption, economic growth, and CO2 emissions, indicating a pathway for further investigation in this area. Additionally, research could delve into the broader implications of health expenditure on economic growth and its relationship to various forms of pollution emissions within a comprehensive multivariate framework. This approach would contribute to a more nuanced understanding of the interconnections between economic activities, environmental impacts, and public health outcomes.

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