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Reexamining the Environmental Kuznets Curve in Selected N-11 Countries: The Role of Financial Markets, Institutional Quality, and Environmental Technology

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Abstract

Economic growth is crucial for emerging economies, yet the sustainability of this growth must consider its environmental impact. The Environmental Kuznets Curve (EKC) hypothesis suggests that while economic expansion initially worsens environmental degradation, it can ultimately lead to environmental improvements as income levels rise. This study reexamined the EKC hypothesis in a selected of countries from the Next Eleven (N-11) group. Using a random effects model regression, the analysis examined the effects of gross domestic products, financial market development, institutional quality, and environmental technology on CO_2 emissions. The findings supported the EKC hypothesis, indicating that economic growth initially increased environmental degradation but eventually contributed to improved environmental outcomes. Financial market development was associated with lower CO_2 emissions, suggesting that robust financial systems may promote eco-friendly investments. In contrast, environmental technology exhibited a positive effect on CO_2 emissions, potentially reflecting an early adoption stage were technology increases emissions. Institutional quality did not show a significant impact on CO_2 emissions. Several recommendations were provided balancing economic growth with environmental sustainability.

Keywords: *Carbon dioxide emission, Environmental Kuznets Curve, Environmental Technology, Financial Market, Institutional Quality.*

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INTRODUCTION

Issues related to the relationship between economic growth and environmental degradation are essential, particularly in emerging countries. Emerging countries have different characteristics compared to developed countries. Emerging countries exhibit higher and faster growth than developed countries (Hove & Tursoy, 2019). As emerging economies grow rapidly, their contribution to global environmental issues like climate change increases. This makes their environmental policies and practices increasingly important on a global scale (Čábelková et al., 2023), however, emerging economies often face a dilemma between pursuing rapid economic growth and protecting the environment. As these countries industrialize and urbanize, they tend to experience increased environmental degradation, particularly in the early stages of development (Nguyễn & Phan, 2023) .

Emerging economies now house over 50% of the global population and produce around 40% of global output. However, their economic activities contribute heavily to environmental pollution. With abundant natural resources, these nations can sustain their populations and support global demands, but their growth also intensifies environmental impacts. Therefore, it is essential for these economies to adopt policies that promote sustainable growth while protecting environmental quality (Hove & Tursoy, 2019)

The relationship between economic growth and environmental degradation is explained by Environment Kuznet Curve (EKC). The EKC suggests that as an economy develops, environmental degradation initially increases but then begins to decrease after reaching a certain level of income per capita (Grossman & Krueger, 1995). There are several stages: 1. Early stage: As countries start to industrialize, pollution and environmental degradation increase, 2. Middle stage: Environmental degradation reaches a peak at a certain income level. 3. Later stage: As income continues to rise beyond this point, environmental quality begins to improve.

This research aims to reexamine the EKC hypothesis. This research also tested the role of financial markets, institutional quality, and environmental technology specifically on the selected N-11 countries. The N-11, or Next Eleven, are a group of countries having a high potential of becoming among the world's largest economies in the 21st century. By focusing on these emerging markets, this study provides insights into the relationship between economic growth and environmental degradation in developing countries that are experiencing rapid industrialization and urbanization.

METHODS

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This study used data in macro level from countries categorized as N-11 from 2002-2021. Nigeria was removed from the sample because the incomplete data, so the list of countries include in sample are Bangladesh, Egypt, Indonesia, Iran, Mexico, Pakistan, Philippines, Türkiye, Korea, and Vietnam. Table 1 showed the measurement that was used in this research.

Table 1. Variable Description

Symbols	Variables	Description	Sources
CO2t	Carbon dioxide emission from transportation	Carbon dioxide (CO2) emissions from Transport (Energy) (Mt CO2e)	WDI
CO2be	Carbon dioxide emission from building	Carbon dioxide (CO2) emissions from Building (Energy) (Mt CO2e)	WDI
CO2ic	Carbon dioxide emission from industrial combustion	Carbon dioxide (CO2) emissions from Industrial Combustion (Energy) (Mt CO2e)	WDI
CO2pi	Carbon dioxide emission from power industry	Carbon dioxide (CO2) emissions from Power Industry (Energy) (Mt CO2e)	WDI
GDP	Economic Growth	GDP per capita (constant 2015 US$)	WDI
FM	Financial Market	Financial Market Index	IMF
IQT	Institutional Quality	The average of six indicators based on worldwide governance indicator (Control of Corruption, Government Effectiveness, Political Stability and Absence of Violence/Terrorism, Regulatory Quality, Rule of	WDI

		Law, Voice and Accountability)	
ERT	Environment-Related Technologies	Development of environment-related technologies, % all technologies	OECD

This study used several measurements for calculating carbon dioxide emissions: Carbon dioxide emission from transportation, Carbon dioxide emission from building, Carbon dioxide emission from industrial combustion, and Carbon dioxide emission from power industry. Model 1-4 will be used in this study:

$$\ln\left(CO2t_{i,t}\right) = \beta_0 + \beta_1 \ln\left(GDP_{i,t}\right) + \beta_2 \ln\left(GDP_{i.t}\right)^2 + \beta_3\left(FM_{i,t}\right) + \beta_4\left(IQT_{i,t}\right) + \beta_5\, ln\left(ERT_{i,t}\right) + \varepsilon_{i,t} \quad (1)$$

$$\ln\left(CO2be_{i,t}\right) = \beta_0 + \beta_1 \ln\left(GDP_{i,t}\right) + \beta_2 \ln\left(GDP_{i.t}\right)^2 + \beta_3\left(FM_{i,t}\right) + \beta_4\left(IQT_{i,t}\right) + \beta_5\, ln\left(ERT_{i,t}\right) + \varepsilon_{i,t} \quad (2)$$

$$\ln\left(CO2ic_{i,t}\right) = \beta_0 + \beta_1 \ln\left(GDP_{i,t}\right) + \beta_2 \ln\left(GDP_{i.t}\right)^2 + \beta_3\left(FM_{i,t}\right) + \beta_4\left(IQT_{i,t}\right) + \beta_5\, ln\left(ERT_{i,t}\right) + \varepsilon_{i,t} \quad (3)$$

$$\ln\left(CO2pi_{i,t}\right) = \beta_0 + \beta_1 \ln\left(GDP_{i,t}\right) + \beta_2 \ln\left(GDP_{i.t}\right)^2 + \beta_3\left(FM_{i,t}\right) + \beta_4\left(IQT_{i,t}\right) + \beta_5\, ln\left(ERT_{i,t}\right) + \varepsilon_{i,t} \quad (4)$$

In this model, each country is represented by *i*, with *t* denoting the annual period selected from 2002 to 2021. The constant term and coefficients, labeled as β_0 and β_1 through β_5, correspond to each variable in the analysis, while ε represents the random error term. Carbon dioxide emissions, economic growth, and environment-related technology variables are natural log-transformed, following the approach of (Ali et al., 2020; Saqib et al., 2024; Zhang et al., 2022). EKC hypothesis suggested that β_1 may be positive, indicating that an initial rise in per capita income could worsen environmental quality. In contrast after reaching a certain level, β_2 is expected to be negative, suggesting that as a country grows wealthier and more developed, further income gains may lead to a decline in carbon emissions. Therefore, the relationship of economic growth and carbon dioxide emissions is inverted U-shaped.

After calculating all variables, descriptive statistics were analyzed to assess the data's characteristics. This analysis included the mean, median, and standard deviation, using Stata 18 software. The mean provided the average values of the data in the study, while the standard deviation indicated the extent of data distribution around the mean (Sugiyono, 2015). Following this, panel data regression was conducted. The Chow, LM, and Hausman tests were applied to identify the most suitable model. Subsequently, multicollinearity, autocorrelation, and heteroscedasticity tests were performed to verify that the panel data adhered to the BLUE (Best Linear Unbiased Estimator) criteria (Gujarati & Porter, 2004).

RESULT AND DISCUSSION

The result of descriptive statistics is showed in Tabel 2 The analysis showed clear differences in CO_2 emissions across sectors. The power industry had the highest average emissions (mean = 4.37, range = 2.43–5.81), underscoring its significant impact, while industrial combustion followed with a mean of 3.69 and low variability (std. dev. = 0.79), suggesting consistency across countries. Transportation and buildings also contributed with means of 3.89 and 3.25, respectively, and moderate variability in building emissions (std. dev. = 0.90). Economic growth varied widely (mean = 8.28, range = 6.52–10.40), reflecting income disparities likely affecting environmental policy. Financial market development showed consistency (mean = 0.37, std. dev. = 0.19), while institutional quality averaged at -0.46 (range = -1.28 to 0.98), indicating governance challenges. Environment-related technology had the greatest variability (mean = 5.68, range = 2.28–11.84), highlighting significant disparities in green tech adoption across countries.

Next, to select the best model, the Chow, LM, and Hausman tests were conducted, and the results indicated that the random effects model was the most suitable. Following this, tests for multicollinearity, autocorrelation, and heteroscedasticity revealed some issues. To ensure robust results, robust standard errors (VCE), Huber-White Sandwich estimator were applied in this case (Huber, 1967)

Table 2. Descriptive Statistics

Variables	Mean	Std.Dev	Min	Max
ln(CO2t)	3.886	0.882	1.349	5.049
ln(CO2be)	3.248	0.895	1.562	5.008
ln(CO2ic)	3.694	0.785	1.415	4.990
ln(CO2pi)	4.368	0.785	2.426	5.807
ln(GDP)	8.275	0.956	6.520	10.397
FM	0.373	0.187	0.076	0.864
IQT	-0.464	0.527	-1.279	0.975
ln(ERT)	5.681	2.367	2.277	11.842

Table 3. Regression Results

	Model 1 (CO2t)	Model 2 (CO2be)	Model 3 (CO2ic)	Model 4 (CO2pi)
ln(GDP)	2.471***	4.143***	6.418***	6.452***
ln(GDP)²	-0.091**	-0.232***	-0.347***	- 0.3193022***
FM	-0.344**	-0.093	-0.530**	- 0.5915063***
IQT	-0.197	-0.397*	-0.193	-.1085916
ln(ERT)	0.068***	0.014	0.035	0.1168528**
R-squared overall	0.590	0.324	0.648	0.471

*,**,***, significant at 10%,5%,1%, respectively

The results for ln(GDP) and its square term, ln(GDP)², are consistent across all models, revealing an inverted U-shaped relationship between economic growth and carbon dioxide emissions. The positive and significant coefficient on ln(GDP) across all models suggests that, in the early stages of economic growth, an increase in GDP is associated with higher CO_2 emissions. This aligns with the initial phase of the EKC hypothesis, where economic expansion leads to increased energy consumption and industrial activity, thereby driving up emissions (Ben Amar, 2021; Maneejuk et al., 2020). The negative and significant coefficient for ln(GDP)² implies that this upward trend eventually reverses at higher income levels. As countries reach a certain threshold of economic development, further increases in GDP lead to a decrease in emissions, possibly due to enhanced environmental awareness, regulatory policies, and investments in cleaner technologies (Ben Amar, 2021; Maneejuk et al., 2020). This finding supports the EKC hypothesis, suggesting a turning point where economic growth transitions from being harmful to beneficial for the environment. However, the exact turning point is not specified in this analysis and warrants further investigation to pinpoint the income level at which emissions begin to decline.

Further, FM shows a negative and significant impact on CO_2 emissions in the transport, industrial combustion, and power industry sectors (Models 1, 3, and 4). This suggests that well-developed financial markets may facilitate the flow of capital into green technologies and sustainable projects, leading to reductions in emissions in these sectors (Hu & Jin, 2023). For instance, in the transportation sector, access to finance may support investments in public transportation infrastructure, electric vehicles, and other low-emission transportation solutions (Benitez & Bisbey, 2021; Puschmann et al., 2020). Similarly, in the power industry, financial markets might encourage investment in renewable energy sources, reducing reliance on fossil fuels (Haas et al., 2001; Xu & Solangi, 2023). Interestingly, FM is not statistically significant in the building sector (Model 2), which could indicate

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that emissions from buildings are less sensitive to financial market dynamics. This might be due to the unique characteristics of the building sector, where emissions are more directly influenced by construction standards, energy efficiency regulations, and building materials rather than financial market accessibility.

Institutional quality, represented by IQT, appears to have a limited impact on CO_2 emissions, with statistically significant results only in the building sector (Model 2) and at a weak level. This weak or non-significant effect across most sectors may indicate that governance quality alone does not directly translate to immediate emissions reductions, although it is likely to play a supporting role. Good governance can indirectly enhance environmental quality by facilitating policy implementation, ensuring regulatory compliance, and fostering a stable environment for investment in green technologies (Du et al., 2023; Khan & Khan, 2023). The weak significance in the building sector could imply that institutional quality might influence emissions through regulatory standards or building codes, where strong institutions are more likely to enforce energy efficiency measures. However, overall, the limited significance of IQT suggests that direct measures aimed at improving institutional quality may not be as immediately effective in reducing emissions as direct financial or technological interventions.

Environment-related technologies (ln(ERT)) show sector-specific effects on CO_2 emissions. In the transportation and power industry sectors (Models 1 and 4), the positive and significant coefficients suggest that the development of environment-related technologies correlates with an increase in emissions. This seemingly counterintuitive finding might be explained by the transitional phase these sectors are undergoing. For example, as these sectors begin integrating new technologies, there may be an initial rise in emissions due to increased production and scaling up of new systems (Darwili & Schröder, 2023; Raihan, 2023). In the early stages of adopting green technologies, there may be an "implementation emissions cost," where emissions increase before the technologies reach their full efficiency and start reducing overall emissions. In the building and industrial combustion sectors (Models 2 and 3), ln(ERT) is not statistically significant, suggesting that environment-related technologies in these areas may either be less impactful or take longer to show measurable effects on emissions. This finding could reflect the specific challenges and adoption lags associated with integrating advanced environmental technologies in these sectors.

CONCLUSION

This study investigated the Environmental Kuznets Curve (EKC) hypothesis across different sectors of carbon dioxide emissions—namely transportation, buildings, industrial combustion, and the power industry—using panel data regression with a random effects model. It also explored the roles of Financial Markets, Institutional Quality, and Environmental Technology. The findings aligned with the EKC hypothesis, showing that while economic growth initially leads to greater environmental degradation, it ultimately fosters improved environmental outcomes.

Based on the result, emerging economies should prioritize financial incentives, such as tax breaks or low-interest loans, for businesses that adopt energy-efficient practices. This would help reduce emissions without hindering economic expansion, aligning growth trajectories with sustainable development goal. Policymakers should therefore focus on strengthening financial markets to support low-carbon technologies. For example, creating green bonds and impact investment funds specifically geared toward low-emission projects in key sectors could enable more robust financing for sustainable projects. Moreover, since environment-related technologies initially raise emissions in transport and power, policymakers should subsidize early adopters and invest in R&D to ease this transitional phase.

This research has several limitations. First, while a panel data regression model was used, it presents certain challenges. Future research could enhance model sophistication by applying approaches like panel ARDL, which would allow examination of both short- and long-term effects of variables. Second, the relatively short study period limits the ability to capture long-term trends. Extending the timeframe could offer a more comprehensive view of the dynamics between variables. Finally, future studies might expand the model by including moderating variables or additional factors not considered here to provide deeper insights into the complex relationships affecting CO_2 emissions.

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