An inverted u-shaped relationship between carbon dioxide emissions and economic growth: The role of institutional quality in developing countries

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ABSTRACT

In the context of developing countries striving to balance economic growth and environmental protection, this study investigates the relationship between carbon dioxide (CO_2) emissions and economic growth, with a particular focus on the moderating role of institutional quality in developing countries. Using panel data from 74 developing economies spanning the period 1995 - 2021, sourced from the World Bank, the analysis reveals two key findings. First, there is evidence of a U-shaped relationship between CO_2 emissions and economic growth, indicating that at early stages of development, growth tends to increase emissions, but beyond a certain point, further growth leads to reduced emissions. Second, institutional quality is shown to play an important role in reducing the carbon dependency of growth. The greater the institutional quality, the weaker the positive relationship between economic growth and CO_2 emissions. This suggests that improved institutions could allow developing nations to follow a less carbon-dependent, more sustainable development path. Such implications for policy carry considerable importance for balancing economic development and environmental sustainability.

1. Introduction

The interplay between carbon dioxide emissions (CO_2), economic growth, and institutional quality has become an increasing focus for a slew of studies in recent years. Today, developing countries face the imperative challenge of reconciling economic growth with environmental sustainability. Unambiguously, reducing poverty, improving living conditions, and commercial/industrial development require rapid economic growth (Bleynat et al., 2021). However, this is done at the cost of degraded environmental quality through increased carbon dioxide emissions and depletion of environmental and natural resource systems (Khan et al., 2022). Many developing economies rely heavily on carbon-intensive industries such as manufacturing, energy production, and mining to drive their growth, making it difficult to transition toward greener alternatives without risking economic slowdown (Nguyen & Dang, 2023). Furthermore, limited financial resources, weak regulatory frameworks, and competing development priorities often constrain efforts to implement effective environmental policies. As a result, achieving sustainable growth requires not only technological advancements and investment in cleaner energy but also significant improvements in institutional quality, governance, and policy coherence. Strengthening

institutions can help create an environment where economic expansion and environmental protection are not mutually exclusive but rather mutually reinforcing goals. However, there has been no comprehensive study assessing the relationship between CO_2 emissions, institutional quality, and economic growth, especially in developing countries.

The correlation between these two factors is often illustrated by the Environmental Kuznets Curve (EKC), which suggests an inverted U-shaped relationship between economic development and environmental degradation, including CO_2 emissions. According to the EKC, in the early phases of development, economic growth typically causes a rise in CO2 emissions, driven by industrialization, urbanization, and heavy reliance on fossil fuels, oil, and gas. Based on the EKC hypotheses, previous studies focused on analyzing the one-way impact of economic growth on CO_2 emissions with many different research samples. Behera and Dash (2017) used the data of South and Southeast Asian regions and assumed that environmental quality worsens with per capita income, and then it improves as income rises after reaching a certain income threshold. Narayan et al. (2016) used data from 181 countries and provided evidence that there is evidence of the EKC hypothesis in 21/181 countries, while income growth reduces future emissions in 49 other countries. While Narayan and Narayan (2010) found that the EKC hypothesis is appropriate in developing countries. In general, previous studies mainly rely on the EKC hypothesis and analyze the unidirectional relationship between growth and carbon emissions, while CO_2 emissions can be an important driving force for growth in developing countries. By analyzing the impact of CO_2 emission on growth, considering the role of institutional quality, our study extends the literature in several ways.

First, we investigate the inverted U-shaped relationship between carbon dioxide emissions and economic growth. To our knowledge, this is the first study to examine CO_2 emissions as a driver of growth. This is relevant for developing countries where lax environmental regulations help attract investment and reduce environmental costs. Our empirical evidence shows that there is an inverted U-shaped relationship between carbon dioxide emissions and economic growth in developing countries. Second, this is the first study to examine the role of institutional quality as a crucial factor influencing this relationship. Institutional quality, encompassing effective governance, anti-corruption efforts, transparency, political stability, and environmental policy coordination, is considered essential for a nation's sustainable development. Specifically, this study provides evidence that institutional quality reduces the positive relationship between carbon dioxide emissions and economic growth. In other words, good institutional quality can help developing countries sustain economic growth with less dependence on CO_2 emissions.

The rest of the paper is structured as follows. Section 2 reviews the relevant literature and develops the research hypotheses. Section 3 describes the data sources, variable construction, and econometric methodology used in the study. Section 4 presents empirical results and discusses the key findings, including the moderating role of institutional quality. Finally, Section 5 concludes the paper by summarizing the main contributions, outlining policy implications, and suggesting directions for future research.

2. Literature review and hypothesis development

2.1. CO_2 emissions and economic growth

The correlation between CO_2 emissions and economic development is commonly illustrated by the EKC hypothesis. In the early stages of development, economic expansion

leads to heightened CO_2 emissions due to industrialization, urbanization, and fossil fuel consumption. However, upon reaching a certain income threshold, nations gain greater capacity to invest in clean technologies, improve energy efficiency, and implement environmental regulations, resulting in a decline in CO_2 emissions despite continued economic growth. Although explaining the inverted U relationship, the ECK hypothesis only explains the unidirectional effect of growth on CO_2 emission. Regarding the effect of CO_2 emissions on economic growth, numerous scholars have explored the mechanisms through which carbon dioxide emissions influence economic growth. According to Gür (2022), CO_2 emissions can serve as a partial indicator of economic activity. As the global carbon balance has deteriorated, the greenhouse effect has worsened, global warming has intensified, environmental pollution has increased, and both economic growth and operational efficiency have been adversely affected (Kourtzidis et al., 2018). These negative consequences stem largely from the overconsumption of energy and the significant release of carbon dioxide into the atmosphere. Lu et al. (2024) demonstrate that newly generated CO_2 emissions have strong predictive capability for the economic growth rate, particularly emissions originating from the transportation and industrial sectors.

The literature examining the relationship between CO_2 emissions and economic development can broadly be categorized into two groups. The first group analyzes this relationship within specific countries, while the second examines it across a cross-section of countries. Representing the first group, Burnett et al. (2013) synthesized the correlation between CO_2 emissions, energy production, and economic growth in the U.S. from 1981 to 2003, using a dynamic ordinary least squares model. Their empirical findings indicate a long-term relationship among the variables consistent with the Environmental Kuznets Curve concept. Similarly, Al-Mulali et al. (2015) studied Vietnam from 1981 to 2011 and found that CO_2 emissions initially declined but later increased with economic growth. Applying an Autoregressive Distributed Lag (ARDL) model, they observed that rising income levels exacerbated pollution, supporting the "pollution haven" hypothesis. For the second group, Yang et al. (2015) investigated the correlation between CO_2 emissions and economic growth using a novel symbolic regression technique. They concluded that a universal model does not fit all countries. Instead, four relationship patterns - inverted N-shaped, M-shaped, inverted U-shaped, and monotonically increasing - were frequently observed, depending on geographical and developmental differences. Wealthier nations often exhibited inverted N-shaped and M-shaped relationships, while emerging economies showed inverted N-shaped, U-shaped, or monotonically increasing patterns. Similarly, Hanif (2017) analyzed data from emerging countries in Latin America and the Caribbean, employing a system Generalized Method of Moments (GMM) with a two-step estimator on a panel of twenty medium- and lower-middle-income economies from 1990 to 2015. His results validated the inverted U-shaped relationship between CO_2 emissions and economic growth, highlighting fossil fuel consumption, oil imports, and urbanization as major contributors to environmental degradation.

Both groups of studies show a complex relationship between CO_2 and economic growth. In developing countries, where policymakers prioritize economic growth, the "pollution haven" hypothesis may be particularly relevant. These countries often adopt lax environmental protection policies to attract investment, thereby creating favorable conditions for production activities and promoting higher growth (Essandoh et al., 2020; Haryanto et al., 2022). Moreover, their economic development tends to rely heavily on manufacturing industries that produce significant CO_2 emissions due to low technological advancement (Geng et al., 2016; Panjaitan et

al., 2023). As a result, expanding these carbon-dependent manufacturing sectors initially helps developing countries sustain strong growth rates. Holtz-Eakin and Selden (1995) find that efforts to control emissions may also reduce economic growth. Olubusoye and Musa (2020) provide evidence that CO_2 emissions increase economic growth in Africa. However, empirical evidence shows that high levels of CO_2 emissions ultimately have a negative impact on the economy. Ampon-Wireko et al. (2022) and Li and Ullah (2022) have found that increased CO_2 emissions place pressure on healthcare systems, reduce the quality of human capital, and force governments to allocate more resources toward environmental protection. Ozturk and Acaravci (2010) provide evidence that CO_2 emission reduces economic growth using data of Turkey. Based on the discussion above, we argue that an inverted U-shaped relationship exists between CO_2 emissions and economic growth in developing countries and propose the following research hypothesis:

H1: There is an inverted U-shaped relationship between carbon dioxide emissions and economic growth

2.2. Institutional quality and CO_2 emission-economic growth relationship

Institutions are the norms and structures that humans have established to guide their actions toward achieving desired goals. Key factors contributing to institutional quality include governance effectiveness, anti-corruption efforts, transparency, political stability, and the coordination of environmental policies (North, 1990). Institutional quality is crucial for achieving a nation's developmental goals, particularly environmental sustainability (Cao et al., 2022; Dang et al., 2022; Nguyen, 2022, 2024b). High-quality institutions ensure the efficient use of state resources, minimize waste, and foster sustainable growth. They uphold the rule of law, enforce regulations, and promote effective governance, thereby encouraging environmentally sustainable behaviors (Towah, 2019). Additionally, institutions can attract Foreign Direct Investment (FDI), which can have either positive or negative environmental impacts (Xaisongkham & Liu, 2024). In general, strong institutions reduce production costs, foster innovation, safeguard state resources, and create favorable conditions for environmental protection. Furthermore, institutional quality enables the effective formulation and enforcement of emission regulations, ensures compliance with environmental standards, promotes corporate investment in clean technologies through transparent incentive structures, and effectively detects and sanctions polluting practices.

Several empirical studies suggest that institutional quality can moderate the relationship between economic activities and environmental degradation. For example, Halkos and Tzeremes (2013) find that countries with better governance structures tend to achieve higher environmental efficiency at similar levels of economic output. Similarly, Song et al. (2011) and Fan et al. (2021) highlight that political stability, regulatory quality, and the enforcement of property rights are essential in reducing pollution levels even during periods of rapid economic growth. Specifically regarding CO_2 emissions, stronger institutions can play a pivotal role by promoting stringent environmental policies, facilitating investment in renewable energy, encouraging innovation, and ensuring compliance with international environmental standards (Farhani & Ozturk, 2015). For instance, Salman et al. (2019) provide evidence that countries with higher institutional quality experience a weaker linkage between economic growth and CO_2 emissions, as institutions enable the transition toward low-carbon economies. Moreover, institutional quality enhances policy effectiveness by reducing corruption, which otherwise often leads to the misallocation of resources and weak

enforcement of environmental regulations (Arora & Chong, 2018; Khan et al., 2023). Through improved coordination of environmental policies and the provision of transparent incentives for green technologies, high-quality institutions can mitigate the environmental costs traditionally associated with economic expansion (Ahmad et al., 2021; Ali et al., 2019).

Thus, based on these theoretical and empirical insights, it is reasonable to expect that institutional quality serves as a moderating factor that weakens the positive association between economic growth and carbon dioxide emissions. Strong institutions can ensure that growth is achieved in a more environmentally sustainable manner, decoupling emissions from output. Based on the discussion above, the following research hypothesis is proposed:

H2: Institutional quality reduces the positive relationship between carbon dioxide emissions and economic growth

3. Methodology

3.1. Data collection

The data used in this paper spans the period from 1995 to 2021 and is publicly available from the World Bank database. This specific timeframe was selected because data before 1995 and after 2021 were either unavailable or inconsistent across countries. The list of countries included in the study is provided in Appendix A (online version). After compiling the data across the selected countries and years, the final dataset comprises a total of 1,084 observations. The key variables collected for the analysis include carbon dioxide (CO_2) emissions, economic growth (GDP growth rate), economic globalization, government debt (as a percentage of GDP), and the World Governance Indicators (WGI), which are used to assess political and regulatory quality. These variables are collected from the World Bank. A detailed description of all variables, including their definitions, measurement units, and data sources, is presented in Table 1.

3.2. Models and estimation method

To test hypothesis H1, we build the model as follows:

$$GROW_{it} = \alpha_1 CO2_{it} + \alpha_2 CO2^2{}_{it} + \alpha_j \sum Control_{it} + \varepsilon \quad (1)$$

To test hypothesis H2, we build the model as follows:

$$GROW_{it} = \beta_1 CO2_{it} + \beta_2 CO2 * WGI_{it} + \beta_j \sum Control_{it} + \varepsilon \quad (2)$$

Where GROW refers to economic growth, it is measured by the natural logarithm of GDP per capita of each country every year. This measure is widely used in previous studies (Alexander, 1997; Nguyen, 2023, 2024a, 2024b). Hence, a higher GROW indicates a higher economic growth rate and reflects how well a country is thriving. CO_2 is CO_2 emission, which is measured by metric tons of CO_2 per capita (Adams & Nsiah, 2019; Lee, 2013). We use the World Governance Index (WGI) to measure institutional quality, which comprises six dimensions: Voice and Accountability, Political Stability and Absence of Violence/Terrorism, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption (Dang et al., 2022; Khan & Hanif, 2020). Control is a vector of control variables including economic globalization (EGI), government debt (GDEBT), government spending (GOVSP), inflation (INF), unemployment rate (UNEM), working population proportion (LABOR), and population growth rate (POG). The previous studies provide evidence that these control variables play an important role in economic growth (Hanushek, 2013; Hussain & Zhou, 2022;

Teixeira & Queirós, 2016; Tran & Nguyen, 2025). α, β are parameters that need to be estimated, and ε is the error term. See Table 1 for all variable definitions.

The growth models 1 and 2 are built based on the literature (Wang, 2009; Wasti & Zaidi, 2020). These data were analyzed using Fixed Effects (FE) and System Generalized Method of Moments (System GMM) estimation techniques. The Fixed Effects model was employed to provide the baseline estimations, accounting for unobserved heterogeneity by allowing each country to have its own intercept. This approach helps control country-specific factors that are constant over time but could otherwise bias the results. To ensure the robustness of the findings, we also applied the System GMM estimator, developed by Arellano and Bover (1995) and Blundell and Bond (1998). System GMM is particularly suitable for dynamic panel data analysis, as it addresses potential issues of endogeneity, measurement errors, and omitted variable bias. By combining equations in levels and first differences and using internal instruments, System GMM improves estimation efficiency and consistency, especially when dealing with short time dimensions and a relatively large number of countries. Using these complementary estimation strategies enhances the credibility of the empirical results by mitigating biases inherent in panel data models and ensuring that the dynamic nature of the relationship between carbon dioxide emissions, economic growth, and institutional quality is properly captured.

Table 1

Variable Description

Variable	Definition and measure	Source
GROW	Natural logarithm of GDP per capita	World Bank
CO_2	CO_2 emissions (metric tons per capita)	World Bank
EGI	The economic globalization index that ranges from 1 to 100 score	World Bank
GDEBT	Government debt (%GDP)	World Bank
GOVSP	Government spending (%GDP)	World Bank
INF	The inflation rate is measured by the CPI index, which shows the annual percentage change in the cost of a fixed basket of goods and services commonly purchased by consumers	World Bank
UNEM	The percentage of the labor force that is without work but available for and seeking employment	World Bank
LABOR	The proportion of the working-age population to the total population by year	World Bank
POG	Population growth rate, which is measured by the annual percentage increase in a country's population	World Bank
WGI	World Governance Index, including 06 components: Voice and Accountability, Political Stability and Absence of Violence/Terrorism, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption	World Bank

Note. This table presents the variable definition. Author's own work

4. Results and discussion

4.1. Descriptive statistics and correlation matrix

Table 2 presents the descriptive statistics of the key variables used in the analysis, including the number of observations, mean, standard deviation, minimum, and maximum values for each variable. The total number of observations for each variable is 1,049. The dependent variable, GROW (log of GDP per capita), has a mean value of 7.794 with a standard deviation of 1.127, suggesting moderate variation in income levels across countries. The range extends from a minimum of 4.932 to a maximum of 9.927, capturing both low- and high-income countries in the sample. CO_2 emissions, measured in metric tons per capita, exhibit significant variety, with a mean of 2.557 and a maximum of 31.132, underscoring inequalities in environmental effects between countries. The World Governance Index (WGI) has a mean of around -0.119, with a range extending from -1.21 to 1.143, reflecting a wide array of governance quality across nations.

Table 2

Descriptive Statistic

Variable	Obs	Mean	Std. Dev.	Min	Max
GROW	1,049	7.794	1.127	4.932	9.927
CO_2	1,049	2.557	3.736	0.001	31.132
EGI	1,049	52.438	12.472	20.730	85.190
GDEBT	1,049	51.936	28.305	6.600	224.750
GOVSP	1,049	15.280	6.206	0.910	43.480
INF	1,049	7.448	30.359	-9.600	1058.400
UNEM	1,049	7.400	6.092	0.140	30.310
LABOR	1,049	62.685	9.131	40.560	86.720
POG	1,049	1.501	1.346	-16.880	16.630
WGI	1,049	-0.119	0.435	-1.210	1.143

Note. This table presents the descriptive statistic of the variables. See Table 1 for variable definitions. Author's own work

Table 3 illustrates the matrix that displays the correlation among all variable pairs. Upon analyzing the correlations between the variables and the dependent variable GROW, it is evident that they are strongly positive with EGI (0.628***), moderately positive with WGI (0.637***), and weakly positive with CO_2 (0.527***). Nonetheless, there is a negative correlation with LABOR (-0.334***) and POG (-0.458***). GDEBT has little or non-significant associations, but INF is strongly inversely linked with GROW at -0.054**. To examine the potential issue of multicollinearity, we analyzed the pairwise correlation matrix among the main variables. While some moderate correlations were observed, particularly between GDP per capita, economic globalization, and institutional quality, none of the pairwise correlation coefficients exceeded the commonly accepted threshold of 0.8. This suggests that severe multicollinearity is unlikely to be a concern. Nevertheless, to further confirm this, we conducted Variance Inflation Factor (VIF) tests, and the results indicated that multicollinearity does not pose a significant problem for the regression estimations.

Table 3

Pairwise Correlations Matrix

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
(1) LGDPS	1.000									
(2) CO_2	0.527***	1.000								
(3) EGI	0.628***	0.406***	1.000							
(4) GDEBT	0.018	0.040	0.072***	1.000						
(5) GOVSP	0.232***	0.242***	0.234***	0.200***	1.000					
(6) INF	-0.054**	0.051**	-0.033	0.057**	-0.027	1.000				
(7) UNEM	0.284***	0.137***	0.242***	0.015	0.471***	0.035	1.000			
(8) LABOR	-0.334***	-0.177***	-0.224***	-0.099***	-0.140***	-0.024	-0.472***	1.000		
(9) POG	-0.458***	-0.363***	-0.444***	-0.035	-0.220***	-0.083***	-0.345***	0.277***	1.000	
(10) WGI	0.637***	0.364***	0.575***	0.223***	0.336***	-0.065**	0.314***	-0.150***	-0.459***	1.000

Note. *** p < 0.01, ** p < 0.05, * p < 0.1. See Table 1 for variable definitions. Author's own work

4.2. Main results

Table 4 presents the results of a regression analysis of Equation (1) using GROW (economic growth) as the dependent variable, applying the fixed-effects method. The primary objective is to examine the inverted U-shaped relationship between CO_2 emissions and economic development. The results show that CO_2 has a positive and statistically significant effect on GROW (0.863***), indicating that higher carbon dioxide emissions are associated with higher GDP levels. However, the squared term of CO_2 (CO22) has a negative and statistically significant effect (-0.054***), suggesting that beyond a certain threshold, further increases in emissions are detrimental to economic growth. This combination of signs validates the existence of an inverted U-shaped relationship. Therefore, the findings support Hypothesis H1: There is an inverted U-shaped relationship between carbon dioxide emissions and economic growth. This result is consistent with our expectations. In other words, during the initial phase of expansion and in lower economic brackets - characteristic of many emerging nations - industrialization, urbanization, and reliance on fossil fuels are the primary contributors to carbon dioxide emissions. First, countries prioritize economic advancement and poverty alleviation over environmental conservation. Second, economic growth often correlates positively with pollution due to weak environmental regulations, heavy dependence on energy-intensive industries, and limited access to clean technologies. At the inflection point, as nations attain middle-income status, several significant changes typically occur. First, public awareness and demand for cleaner environments increase. Second, structural transitions take place, with economies gradually shifting from agriculture and heavy industry toward services and sustainable technologies. Third, governments begin implementing stricter environmental regulations and allocate greater resources toward the development of sustainable infrastructure.

The control variables also provide meaningful insights. Economic globalization (EGI) positively influences growth, showing that greater integration into the global economy benefits developing countries. Government debt (GDEBT) and inflation (INF) negatively impact economic growth, reflecting fiscal and monetary vulnerabilities often faced by emerging economies. Similarly, unemployment (UNEM), lower labor force participation (LABOR), and rapid population growth (POG) are associated with reduced GDP per capita. Although governance quality (WGI) shows a negative but insignificant coefficient, this may suggest that institutional improvements alone are not sufficient to drive growth without complementary reforms in other sectors.

These findings are particularly relevant for developing countries, where rapid industrialization often comes at the cost of environmental degradation. The inverted U-shaped relationship illustrates the challenge of balancing economic growth with environmental sustainability. Moreover, the influence of globalization and the adverse effects of macroeconomic instability highlight the structural vulnerabilities that developing countries must manage carefully. Overall, the model appropriately captures the developmental dynamics of emerging economies, reinforcing the importance of adopting growth strategies that account for both economic expansion and environmental protection.

Table 4

Inverted U-shape Relationship between CO_2 Emission and Economic Growth

Dependent variable: GROW	**Coefficient**	**T-stat**
CO_2	0.863***	15.84
CO22	-0.054***	-10.33
EGI	0.015***	6.40
GDEBT	-0.007***	-10.98
GOVSP	0.009*	1.71
INF	-0.010***	-5.59
UNEM	-0.027***	-4.39
LABOR	-0.042***	-8.92
POG	-0.070***	-3.92
WGI	-0.094	-1.33
Cons	8.901***	24.21
F-test (p-value)	0.000	
Number of observation	1,049	

Note. This table reports the estimation results of Equation 2. CO_2 * WGI is calculated by multiplying CO_2 by WGI. See Table 1 for variable definitions. *** p < 0.01, ** p < 0.05, * p < 0.1. See Table 1 for variable definitions. Author's own work

Table 5 analyzes the moderating influence of institutional quality (WGI) on the correlation between carbon dioxide emissions and economic growth, particularly within emerging nations. The interaction term is negative and significant, indicating that superior institutional quality diminishes the beneficial effect of carbon dioxide emissions on economic development. This suggests that improved governance fosters cleaner, less carbon-intensive economic trajectories. The negative relationship for CO_2 * WGI (-0.105***) indicates that institutional quality influences economic growth, transitioning it from a focus on expansion at any expense to a more sustainable, efficient, and environmentally aware development model. Table 5 presents the estimation results examining the moderating role of institutional quality in the relationship between CO_2 emissions and economic growth. The coefficient on CO_2 remains positive and statistically significant (0.332***), indicating that carbon emissions continue to promote economic growth. However, the interaction term CO_2 * WGI is negative and statistically significant (-0.105**), confirming that better institutional quality reduces the positive effect of CO_2 emissions on economic growth. In other words, stronger institutions help weaken the traditional growth-emissions linkage, making economic development less dependent on pollution-intensive activities. This finding supports Hypothesis H2 and suggests that improvements in governance, regulatory quality, and institutional effectiveness enable countries to pursue economic growth paths that are less reliant on carbon emissions. Therefore, institutional quality plays a critical role in promoting sustainable development by facilitating cleaner growth strategies and reducing the carbon intensity of economic advancement. This outcome also supports previous studies such as Lewis (2007), Wawrzyniak and Doryń (2020), Almustafa et al. (2023), and again demonstrates the important role of institutional quality in conducting economic policies.

Table 5

Institutional Quality and CO_2 Emission-Economic Growth Relationship

Dependent variable: GROW	**Coefficient**	**T-stat**
CO_2	0.332***	15.60
CO_2 * WGI	-0.105***	-2.84
EGI	0.019***	8.30
GDEBT	-0.007***	-11.09
GOVSP	0.006	1.09
INF	-0.012***	-6.27
UNEM	-0.025***	-3.77
LABOR	-0.043***	-8.76
POG	-0.064***	-3.40
WGI	-0.006	-0.07
Cons	9.408***	24.55
F-test (p-value)	0.000	
Number of observations	1049	

Note. This table reports the estimation results of Equation 1. CO22 represents the squared term of CO_2. See Table 4 for variable definitions. *** p < 0.01, ** p < 0.05, * p < 0.1. See Table 1 for variable definitions. Author's own work

The results presented in Table 5 are particularly appropriate for developing countries, where rapid economic growth is often closely tied to activities that generate high levels of carbon emissions, such as manufacturing, construction, and resource extraction. In these economies, institutional frameworks are typically weaker, and environmental regulations are either underdeveloped or poorly enforced. The finding that stronger institutional quality reduces the positive effect of CO_2 emissions on economic growth is significant because it highlights a practical pathway for developing countries to achieve more sustainable growth. As governance, regulatory quality, and anti-corruption measures improve, these countries can shift their growth models away from carbon-intensive industries toward cleaner, more innovation-driven sectors. This transition is essential for developing countries because it allows them to continue growing economically while minimizing long-term environmental damage and avoiding the "pollute first, clean up later" trap. In short, improving institutional quality offers developing countries a viable strategy to balance their urgent need for growth with their future need for environmental sustainability.

4.3. Robustness test

To ensure the robustness and reliability of the main findings, Table 6 reports the results from the System GMM estimation. This method is particularly suitable for dynamic panel data models, where potential endogeneity, autocorrelation, and unobserved heterogeneity may bias traditional estimators. By including the lagged dependent variable (Lag(GROW)) in models 1 and 2, system GMM accounts for the dynamic nature of economic growth. Both models (1) and (2) yield statistically significant and large coefficients for Lag(GROW) (0.856*** and 0.870***), confirming the persistence of growth over time.

The key relationships observed in earlier fixed-effects estimations are broadly confirmed under System GMM. In model (1), CO_2 remains positive and statistically significant (0.067**), while CO22 is negative and weakly significant (-0.005*), again supporting the inverted U-shaped relationship between CO_2 emission and economic growth. The hypothesis H1 continues to be supported. Model (2) further reinforces Hypothesis H2 by including the interaction term CO_2 * WGI, which is negative and statistically significant (-0.059) while the coefficient of CO_2 remains positive, indicating that institutional quality continues to reduce the positive impact of CO_2 emissions on economic growth. Moreover, institutional quality (WGI) itself becomes strongly significant in model (2) (0.413**), emphasizing its role in fostering growth when properly integrated with environmental concerns. The control variables are generally consistent with earlier findings. The robustness checks not only confirm the validity of the baseline model but also reinforce the importance of institutional quality in moderating the growth-emissions relationship in developing countries. The Arellano-Bond AR(2) test p-values (0.142 and 0.112) and the Hansen test p-values (0.593 and 0.460) suggest no evidence of second-order serial correlation and no over-identification problems, thereby validating the model specification and instrument relevance.

Table 6

Robustness Test Results Using System GMM Method

Dependent variable: GROW	**(1)**		**(2)**	
	Coef.	**T-stat**	**Coef.**	**T-stat**
Lag(GROW)	0.856***	37.19	0.870***	34.97
CO_2	0.067**	2.22	0.027**	2.35
CO22	-0.005*	-1.85		
CO_2 * WGI			-0.059*	-1.86
EGI	-0.001	-0.46	0.001	0.38
GDEBT	-0.001**	-2.05	-0.001	-1.43
GOVSP	-0.003	-1.60	-0.004	-1.25
INF	-0.003	-1.40	-0.001	-0.41
UNEM	-0.001*	-1.75	-0.004	-1.21
LABOR	-0.002	-1.63	-0.005***	-2.67
POG	-0.027	-1.62	0.050**	2.18
WGI	0.135**	2.80	0.413**	2.50
Cons	1.430***	6.69	1.416***	4.42
AR(2) test (p-value)	0.142		0.112	
Hansen test (p-value)	0.593		0.460	
Number of observations	874		874	
Number of instruments	72		67	

Note. This table reports the estimation results of Equations 1 and 2 applying the system GMM method. Regressions 1 and 2 present the results of Equations 1 and 2, respectively. See Table 1 for variable definitions. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. See Table 1 for variable definitions. Author's own work

5. Conclusion

This study examines the relationship between carbon dioxide (CO_2) emissions and economic growth in developing countries, with a particular emphasis on the moderating role of institutional quality. Using panel data from 74 developing economies between 1995 and 2021, the analysis yields two important findings. First, the results confirm the presence of an inverted U-shaped relationship between CO_2 emissions and economic growth. This suggests that low CO_2 emissions can boost economic growth in developing countries because environmental sacrifices can promote the development of key industries and attract foreign investment, but as developing countries face emissions that exceed necessary thresholds, CO_2 emissions will constrain growth. Second, the study finds that institutional quality significantly reduces the dependence of economic growth on carbon emissions. In countries with stronger institutions, the positive link between growth and emissions weakens, highlighting the crucial role governance plays in promoting sustainable development.

These findings have important policy implications for developing countries striving to achieve economic progress without sacrificing environmental goals. Improving institutional quality - through stronger rule of law, effective governance, regulatory quality, and anti-corruption measures - can enable developing economies to shift toward cleaner and more sustainable growth trajectories. In this context, policies aimed at institutional reforms should be considered a central pillar of green growth strategies. Strengthening institutions not only supports better environmental outcomes but also reinforces overall economic resilience, helping countries manage long-term development challenges more effectively. In addition, the research results also help policymakers in developing countries to be cautious about policies that trade off the environment for growth goals. Excessive CO_2 emissions not only do not help promote growth but also hinder growth.

Future research could address these limitations by exploring more granular, sector-level analyses to capture differences across industries and regions. Moreover, incorporating variables related to technological progress, renewable energy adoption, and environmental policy frameworks would provide a more comprehensive understanding of the transition toward low-carbon growth. Longitudinal case studies focusing on specific countries undergoing institutional reforms could also offer deeper insights into how governance improvements translate into sustainable economic and environmental outcomes over time.

SCIENTIFIC CONTRIBUTION

The manuscript clearly identifies a research gap; the manuscript opens new directions for further research; the manuscript extends or refines existing theories; the manuscript provides new datasets or empirical evidence; the manuscript presents statistically and practically significant findings; the manuscript opens new directions for further research.

AUTHOR CONTRIBUTIONS

CRediT: **Nguyen Quang Khai**: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Supervision, Project Administration; **Phan Thi Minh Hue**: Writing - Review & Editing, Investigation, Formal Analysis; **Pham Nguyen Thanh Nhan**: Writing - Review & Editing, Investigation, Formal Analysis.

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NO CONFLICT OF INTEREST STATEMENT

All authors declare that they have no conflict of interest.

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