



Full Length Article

Greening the future: Do green growth and institutional quality affect environmental sustainability differently across countries' income levels? International evidence

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ARTICLE INFO

Keywords:

Green growth
Institutional quality
Carbon emissions
Environmental sustainability

ABSTRACT

This study examines whether green growth and institutional quality index (i.e. anti-corruption, political stability, rule of law, voice and accountability, regulatory quality and government effectiveness) of selected 40 countries increase or reduce carbon dioxide (CO₂) emissions from 2000 to 2021. For the analysis, the study divided the full panel sample of 40 countries into low-middle-income countries (17 countries) and high-upper-income countries (23 countries). The study utilizes the Method of Moment Quantile Regression (MM-QR) to address variables endogeneity. The results indicate three (3) main findings: i) For a full panel sample, green growth reduces CO₂ emissions; ii) for the sub-sample analysis, green growth reduces CO₂ emissions in low-middle-income countries but does not contribute to the reduction of CO₂ emissions in high-upper-income countries; iii) for a full panel and sub-sample analysis, institutional quality increases CO₂ emissions in low-middle and high-upper-income countries. Overall, the results suggest that green growth matters for future CO₂ reduction. However, high-and upper-income countries have insufficiently decoupled their CO₂ emissions from GDP growth. The study recommends that high-and upper-income countries should adopt green growth policies. The policy implications include strengthening institutional quality in high-upper and low-middle-income countries to improve environmental regulations, laws, and other related policies that minimize CO₂ emissions to achieve environmental sustainability.

1. Introduction

The high demand for energy, particularly fossil fuels in the transportation, residential, commercial, and industrial sectors in both developed and developing countries, faces significant challenges in balancing high economic growth, net-zero emissions targets, and environmental sustainability (Halpe et al., 2025; Raihan et al., 2025). These sectors rely primarily on fossil fuels, where pollution is greater while impacting global climate change. For instance, higher economic growth leads to higher carbon dioxide (CO₂) emissions, industrialization and rapid urbanization, which in turn can affect the quality of the environment (Byaro et al., 2024; Siddique & Alvi, 2025; Sikder et al., 2022).

The world urgently needs a carbon reduction agenda to be resilient to climate change. Neglecting climate action could potentially undermine some of the Sustainable Development Goals (SDGs). For example, higher

carbon emissions and annual temperature rise can negatively impact food security (SDG 2), health (SDG 3), and economic growth (Byaro, 2025; Byaro & Rwezaula, 2025). Global carbon emissions have been increasing steadily for years, and the proportion of CO₂ emissions are different for each region of the world. For example, North America and Asia each contribute 29 % of global carbon emissions (Ritchie & Roser, 2024). Europe contributes 33 % of global CO₂ emissions, while Africa and South America each contribute 3 % of global CO₂ emissions (Ritchie & Roser, 2024). Oceanic contributes 1.2 % of global carbon dioxide emissions (Ritchie & Roser, 2024).

Studies have suggested various measures to curb CO₂ emissions, including quality of governance, carbon pricing, promoting sustainable transportation, renewable energy sources, sustainable agricultural practices, investing in research and development, green growth, and strict environmental regulations (Abbas et al., 2024; Byaro et al., 2023;

This article is part of a special issue entitled: Green Growth published in Innovation and Green Development.

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<https://doi.org/10.1016/j.igd.2025.100276>

Received 5 January 2025; Received in revised form 7 June 2025; Accepted 8 June 2025

Available online 1 August 2025

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Cheikh et al., 2025; Dam et al., 2024; Dill, 2024; Khan et al., 2024; Lin & Ullah, 2024; Nasir et al., 2024; Raihan et al., 2024; Yikun et al., 2023; Yu et al., 2024). There is a need for a global effort to address climate change and lower CO₂ emissions, mainly by shifting to green growth, enhancing governance quality, and enacting sustainable natural resource use (Dam et al., 2024; Lin & Ullah, 2024; Mehboob et al., 2024; Thi & Do, 2024).

Green growth is defined as environmentally conscious economic expansion aimed at reducing emissions. Countries need to achieve economic growth without harming the environment, using sustainable technologies and cleaner production methods (Danish & Ulucak, 2020). Green growth includes all production-related areas, including GDP growth, energy consumption, urban population growth, air pollution, industrial value added, and research and development expenditure (Ajayi & Pollitt, 2024). It also captures relevant information on environmental issues linked to input and output factors including broad environmental, economic, and social factors (Sun et al., 2020; Tawiah et al., 2024). The environmental sustainability benefits of green growth include reducing CO₂ emissions, promoting clean technology innovation and long-term economic resilience (Amin et al., 2025). Despite these benefits, the extent to which green growth can ensure environmental sustainability remains a subject of ongoing debate (Wei et al., 2025). For example, Hickel and Kallis (2019) argued that the high use of resources and carbon emissions in advanced countries does not support the theory of green growth. Similarly, Zhao, et al. (2023a,b) noted that green growth does not always result in significant reduction of carbon emissions.

On the other hand, governance quality linked with environmental sustainability is crucial in shaping the future green growth path (Abid, 2016; Muhammad & Long, 2021; Sheng et al., 2023). Governance institution indicators include the rule of law, regulatory quality, government effectiveness, voice and accountability, political stability, and control of corruption, which are crucial to developing and implementing policies that explain how different countries protect natural resources and conserve the environment. Thus, studying the impact of governance on environmental sustainability provides a clear insight into how institutional quality can contribute to achieving CO₂ reduction. Moreover, studying green growth and institutional quality across different income countries are crucial for developing effective policies to reduce CO₂ emissions while promoting sustainable economic development. Notably, the impact of green growth and institutional quality on environmental sustainability may vary based on the country's economic status. Another key motivation for this study is the UN Sustainable Development Goals (SDGs), mainly SDGs 13 and 8, which focus on climate action and economic growth.

Recently, many developing countries in Asia and Africa have faced challenges of weak governance and political instability (Asif et al., 2024; Bekun et al., 2024; Beyene, 2024; Ghanayem et al., 2023; Traoré et al., 2024), which in turn can affect the entire process of sustainable environmental practices. The literature suggests that good governance has a positive impact on reducing CO₂ emissions and achieving a greener economy (Awewomom et al., 2024; Zhao, Samour, et al., 2023). Quality governance enhances environmental sustainability for current and future generations and is related to the effectiveness and resilience of financial institutions (Byaro et al., 2024).

Against this background, the study examines the impact of green growth and the quality of institutions in addressing environmental sustainability, utilising updated data for an international full panel sample of 40 countries selected between 2000 and 2021. Additionally, previous studies have used green growth and institutions quality to examine its impact on CO₂ emissions, such as Abid (2017), Ahakwa et al. (2024), Fabrice et al. (2024), Obobisa et al. (2022), and Sheng et al. (2023). However, no direct consensus is drawn from these studies, as green growth and institutional quality produce mixed findings regarding CO₂ emissions. Some studies suggest that institutional quality decreases or increases CO₂ emissions, while others indicate that green growth reduces CO₂ emissions (Khan & Rana, 2021). Moreover, studies

examining the combined effect of green growth and institutional quality on CO₂ emissions have been limited in an international context. From this perspective, the study examines whether green growth and institutional quality can help reduce CO₂ emissions and contribute to achieving environmental sustainability goals. It also examines whether green growth and institutional quality influence environmental sustainability differently depending on the country's income levels.

This study contributes to existing literature and fills the gaps in various aspects. First, it focuses on an international panel sample of 40 countries from Asia, Europe, Latin America, Africa and Oceania using an updated time framework from 2000 to 2021. Second, it utilizes a green growth and institutions quality index constructed from six variables (i.e. rule of law, regulatory quality, government effectiveness, voice and accountability, political stability, and control of corruption) to predict how these measures can reduce CO₂ emissions in an international perspective and achieve environmental sustainability goals. It is worth noting that most studies used institutional quality variables separately rather than combining all six governance indicators into a single index (see Acheampong & Said, 2024; Dam et al., 2024). Thirdly, a panel sample of the selected 40 countries is divided into low-middle and high-upper income countries to explore whether green growth and institutional quality impact environmental sustainability depending on each country's income level.

Fourth, our study focuses on environmental sustainability to ensure that international countries work together to reduce greenhouse gas emissions and achieve the 13 Sustainable Development Goals (SDG) through climate action. Fifth, the study employs the Method of Moment Quantiles Regression (MM-QR) and robustness check using Kernel Regularized Least Squares (KRLS) to explain the relationship between green growth and institutional quality on CO₂ emissions. These two econometric methods are employed to investigate whether there is a nonlinear relationship between green growth, institutional quality, and achieving environmental sustainability. This study excluded conventional econometric techniques because it estimates linear models, implying that the relationship between green growth and institutional quality on CO₂ emissions is expressed in a linear form. At the same time, in real life, many variables have nonlinear relationships. KRLS is applied for a robustness check because of its ability to handle non-linearity. Most of the previous studies have heavily relied on conventional (i.e. frequentist) panel estimates such as Autoregressive Distributed Lag (ARDL), Generalized Method of Moment (GMM), Cross-sectional Autoregressive distributed lag (CS-ARDL), and other co-integration tests (Acheampong & Said, 2024; Dam et al., 2024; Kabiru et al., 2023; Kwakwa, 2023; Murshed, 2024; Sajid et al., 2024).

Combining KRLS and the Method of Moment Quantile (MM-QR) regression can reveal the impact of green growth and institutional quality on increasing or reducing carbon emissions. Sixth, the study explores the mechanisms of green growth and institutional quality to influence CO₂ emissions. To this end, the study provides a comprehensive analysis of a full panel sample of 40 countries and their sub-sample of high-upper and low-middle income countries, offering insight to the policymakers and the public on whether institutional quality and green growth can reduce CO₂ emissions and enhance environmental sustainability. In addition, the study incorporated labour productivity (i.e. labour force participation), real interest rate, capital formation, and government expenditure as control variables in the model to differ from other previous studies that consistently used trade, economic growth, urbanization, industrialization, population growth, and renewable energy as control variables in green growth-institution quality nexus CO₂ emissions.

In general, the study highlights three novelties. First, it employs both the Methods of Moment Quantile Regression (MM-QR), as recommended by Machado and Santos Silva (2019) and Kernel Regularized Least Square (KRLS) regression as a robustness test to investigate the full-sample analysis of 40 countries on the impact of green growth and institutional quality on environmental sustainability. Second, the full

panel sample is divided into low-middle and high-upper-income countries to examine whether green growth and institutional quality impact environmental sustainability depending on each country's income level. Third, constructing the Principal Component Analysis (PCA) index of institution quality from six governance indicators (i.e. control of corruption, political stability, rule of law, voice and accountability, government effectiveness, and regulatory quality) presents another novelty.

To address this purpose, the study poses three important research questions. First, do green growth and institutional quality improve or worsen CO₂ emissions for the chosen 40 sample countries? Second, do institutional quality and green growth have varying effects on environmental sustainability across countries' income levels? Third, is there a nonlinear relationship between green growth and institutional quality towards CO₂ emissions? This analysis can reveal the inconclusive nature of institutional quality and green growth on environmental sustainability.

The rest of the study is structured as follows: Section two presents a literature review, section three presents the data sources and methodology, section four reports the results and interpretations, and the final section provides a conclusion and policy implications.

2. Literature review

2.1. Theoretical literature

This section presents the Green Solow model and institutional theory to examine the role of green growth and institutional quality in influencing CO₂ emissions, achieving environmental sustainability goals and addressing climate action through sustainable development goals. The Green Solow Model extends the traditional Solow growth model by integrating environmental factors, specifically concentrating on the relationship between economic growth and CO₂ emissions. It asserts that technological advancements can promote a decoupling of economic growth from environmental degradation (Brock & Taylor, 2010). In this model, sustainable growth can be accomplished when investments in clean technologies and energy efficiency exceed the increase in emissions resulting from economic activities.

In this regard, green growth is one of the most essential initiatives in economic development with environmental sustainability, especially related to carbon emissions (Hao et al., 2023; Zahra & Fatima, 2024). It aims to implement measures that reduce environmental degradation and carbon emissions, thereby promoting economic growth and the adoption of innovative technology (Baniya et al., 2021; Tan & Cao, 2023; Udeagha & Ngepah, 2023). For example, advances in low-carbon technologies such as electric vehicles and renewable energy sources (solar, wind, and hydroelectric) are necessary to reduce greenhouse gas emissions. Meanwhile, in the process of economic growth to achieve green growth, strong policy interventions, technological innovation, and strong institutional frameworks are required to manage environmental sustainability (Arvin et al., 2022; Bekun et al., 2021; Hassan et al., 2020; Khan et al., 2022; Salman et al., 2019).

On the other hand, institutional theory emphasizes the significance of governance, policies, and institutional frameworks in influencing environmental outcomes such as CO₂ emissions (Kabiru et al., 2023; Khan & Rana, 2021; Panayotou, 1997). It suggests that effective institutions can facilitate the implementation of sustainable practices and encourage adherence to environmental regulations. This theory underscores how institutional quality, such as transparency, accountability, and regulatory enforcement, influences a country's ability to manage its environmental impact. High-quality institutions with strong governance, effective regulation, and low levels of corruption are essential for implementing environmental policies to reduce carbon emissions. Meanwhile, effective and strong institutions implement environmental regulations, ensure compliance, and promote transparency, thereby reducing practices that contribute to environmental degradation (Awewomom et al., 2024; Lau et al., 2014).

In the context of institutional quality, the Environmental Kuznets Curve (EKC) hypothesis suggests that improvements in institutional quality as economic growth increases can lead to reductions in carbon emissions through better regulatory frameworks and more effective environmental policies (Byaro et al., 2024). In countries with weak institutions, corruption can hinder the implementation of environmental policies and lead to higher emissions and environmental degradation (Bhattarai & Hammig, 2001; Fredriksson & Svensson, 2003; Salman et al., 2019). Generally, inadequate and poor institutions increase pollution, while strong institutions reduce it. This implies that institutional quality is crucial for achieving sustainable development and mitigating the impacts of climate change (Byaro et al., 2024). Therefore, the Green Solow Model and Institutional Theory offer a comprehensive understanding of how green economic growth and institutional quality contribute to reducing CO₂ emissions in different countries.

2.2. Empirical literature review

Table 1 summarizes the empirical literature related to green growth, institutional quality, and CO₂ emissions for different countries. In contrast, previous studies indicate that institutions have various effects on CO₂ emissions. For instance, institutional quality increases CO₂ emissions (Acheampong & Said, 2024; Obobisa et al., 2022), while others claim institutional quality has a neutral impact (Kabiru et al., 2023). Most of the findings suggest that institutional quality reduces CO₂ emissions (Abid, 2016; Khan & Rana, 2021; Kwakwa, 2023; Lau et al., 2023; Murshed, 2024; Sheng et al., 2023; Stef et al., 2023), among others. It also shows that green innovation or growth has an overall impact on reducing CO₂ emissions (Ahakwa et al., 2024; Borgi et al., 2024; Chang et al., 2023; Huang, 2023; Mehmood et al., 2024; Sajid et al., 2024; Wu et al., 2024; Zakari, 2024). Some studies show that green growth does not reduce carbon CO₂ emissions (Dash et al., 2024; Gazheli et al., 2016). Overall, previous studies rarely addressed the combined impact of green growth and institutional quality using international evidence.

2.2.1. Literature gaps

While reviewing the empirical literature on the impact of green growth and institutional quality on CO₂ emissions, we found that very few studies applied MM-QR, and none applied KRLS. Similarly, most previous studies used different institutional quality indicators separately (see Acheampong & Said, 2024; Dam et al., 2024). In this regard, our study developed an institutional quality index based on six governance indicators (rule of law, anti-corruption, government effectiveness, regulatory quality, voice and accountability, political stability) using principal component analysis (PCA). In addition, most studies have shown that the impact of institutional quality on carbon emissions is negative and linear (Lau et al., 2023; Murshed, 2024; Sajid et al., 2024). In this view, a nonlinear relationship between institutional quality and CO₂ emissions may provide policymakers with essential insights.

Another difference in the literature is that we split the panel analysis of the full sample of 40 countries into low-middle and high-upper-income countries to explore whether green growth and institutional quality have different impacts on environmental sustainability on countries' income levels. Overall, no studies have analyzed the combined impact of governance and green growth on environmental sustainability in low-middle and upper-middle-income countries. To this end, the study fills these gaps in existing literature.

3. Data and methodology

3.1. Data sources

The annual data are from 40 selected countries in five regions, including Asia, Europe, Latin Americas, Africa and Oceania, from 2000 to 2021. As each region contributes to global CO₂ emissions, the 40

Table 1
Summary of literature review.

SN	Author (s)	Period	Country	Methodology	Key Findings
a) Institutional quality nexus environmental sustainability					
1.	Acheampong and Said (2024)	2004–2020	119 countries globally	Two-step Generalized Method of moments (GMM)	Quality of governance increases CO ₂ emissions.
2.	Kabiru et al. (2023)	2008–2020	45 Sub-Saharan African Countries	Two-step systems Generalized Method of Moments (GMM)	Institutional quality has a neutral impact on CO ₂ .
3.	Liu and Zhang (2024)	1998–2022	BRICS Countries	Advanced econometric models such as FMOLS, DOLS and CS-ARDL	Governance mechanisms improves environmental sustainability.
4.	Kwakwa (2023)	2002–2021	32 African countries	Full Modified OLS	Institutions reduce CO ₂ emissions.
5.	Stef et al. (2023)	1996–2016	136 countries	AI Models	Rule of law is effective in curbing CO ₂
6.	Khan and Rana (2021)	1996–2015	41 Asian Countries	Panel co-integration method and panel Vector Error Correction Models (VECM)	Institutional quality contributes to the reduction of CO ₂ in Asia.
7.	Murshed (2024)	1996–2021	10 countries	Dynamic Common Correlated Effects (CS-ARDL)	Good governance reduces CO ₂ emissions.
8.	Borgi et al. (2024)	2000–2021	G7 Countries	Regression models	Renewable energy led to a reduction in CO ₂ emissions in the presence of governance.
9.	Sajid et al. (2024)	1996–2021	China and Pakistan	Autoregressive Distributed Lag (ARDL) approach	Institutional quality lowers the risks of emissions in China
10.	Chang et al. (2023)	2003–2019	30 provinces of China	System Generalized Method of Moments (SYS-GMM) and the Difference-In-Difference (DID) models	Environmental regulations and green innovation reduce CO ₂ emissions.
11.	Zheng et al. (2024)	1995–2020	Emerging economies	Method of Moment Quantile	Governance reduces CO ₂
12.	Lau et al. (2023)	1970–2021	USA	The Autoregressive Distributed Lag estimations	Institutional quality reduces CO ₂ emissions
13.	Obobisa et al. (2022)	2000–2018	25 African countries	Common correlated effects mean group (CCEMG) estimators	Institutional quality increases CO ₂ emissions.
14.	Id et al. (2023)	2002–2019	Belt and Road Initiative (BRI) countries	OLS, FE, differential GMM, and two-step systematic GMM	Institutional quality reduces CO ₂ emissions
15.	Ali et al. (2023)	2003–2019	35 OECD economies	Two-stage sequential techniques and GMM	Institutional quality reduces CO ₂ emissions
16.	Udemba (2021)	1996–2018	Chile	Nonlinear and asymmetric approaches	Institutional quality reduces emissions from FDI and fossil fuels.
17.	Abid (2016)	1996–2010	25 SSA	Reduced form modeling	Political stability, government effectiveness, democracy, and control of corruption reduce CO ₂ emissions.
18.	Muhammad and Long (2021)	2000–2016	65 Belt and Road Initiative countries	IV- GMM	Institutional factors such as political stability, the fight against corruption and the rule of law contribute to reducing CO ₂ emissions.
19.	Dam et al. (2024)	1996–2021	30 OECD countries	PMG -ARDL	Institutional quality increases environmental pollution
b) Green growth nexus environmental sustainability					
1.	Ahakwa et al. (2024)	1980–2018	Ghana	Econometric techniques quantile-on-quantile regression	Green energy consumption, green innovation mitigate CO ₂ emissions.
2.	Zhao, et al. (2023a,b)	2004–2018	China	OLS, FMOLS	Green growth reduces CO ₂
3.	Dam et al. (2024)	1996–2021	30 OECD countries	PMG -ARDL	Green growth reduces CO ₂ emissions
4.	Tan and Cao (2023)	1990–2019	G7 and BRICS Countries	Random and fixed effect estimate method	Green technological innovations decrease CO ₂ emissions
5.	Wu et al. (2024)	2006–2022	China	Panel two-way fixed effect model	Green finance significantly contributes to enhancing CO ₂ emission efficiency.
6.	Huang (2023)	2003–2020	30 Chinese provinces	Linear functional-coefficient models	Green innovation reduces CO ₂ emissions
7.	Yadav et al. (2024)	2000–2021	BRICS Nations (Brazil, Russia, India, China and South Africa)	Distributed Lag (CS-ARDL) model	Robust governance and strategic green finance significantly mitigate CO ₂ emissions
8.	Udeagha and Ngepah (2023)	1960–2020	BRICS Countries	Second-generation cross-sectional augmented autoregressive distributed lags (CS-ARDL) framework	Green innovation contributes to a long-term reduction in CO ₂ emissions.
9.	Zakari (2024)	2000–2020	OECD Countries	Panel-corrected standard error (PCSE), method of moments (IV-GMM)	Green transitions play a crucial role in achieving carbon neutrality
10.	Obobisa et al. (2022)	2000–2018	25 African countries	Common correlated effects mean group (CCEMG)	Green technological innovation reduces CO ₂ emissions
11.	Dong et al. (2022)	2006–2017	China 30 Province	System GMM, 2SLS, OLS, Quantile regression.	Green development reduces CO ₂ emissions
12.	Hao et al. (2021)	1991–2017	G7 Countries	Cross-sectional augmented Autoregressive Distributive Lag (CS-ARDL) model	Green growth reduce CO ₂ emissions.
13.	Yuan et al. (2021)	2005–2017	China	STIRPAT model	Green innovation reduces CO ₂ emissions.
14.	Wang and Yang (2022)	1995–2014	78 countries	Expectation (EM) Maximization algorithm	Green products decrease CO ₂ emissions

(continued on next page)

Table 1 (continued)

SN	Author (s)	Period	Country	Methodology	Key Findings
15.	Thi and Do (2024)	1996–2020	71 Countries globally	Three-stage least squares (3SLS)	Green innovation influences emissions negatively
16.	Amin et al. (2025)	1990–2018	China	Wavelet analysis	Green growth reduces CO ₂ emissions
17.	Gazheli et al. (2016)	1995–2007	Denmark, Germany, Spain	Direct carbon intensity and total carbon intensity	Sectors with high carbon intensity tend to grow more, making green growth challenging
18.	Zahra and Fatima (2024)	1990–2020	China	Quantile regression	Green growth leads to a decline in CO ₂ emissions
19.	Dash et al. (2024)	1996–2020	Twelve highly polluting countries (China, US, India, Russia, Japan, South Korea, Canada, Mexico, Turkey, Italy, Poland, UK)	Fixed and random effect models	Despite the expected negative sign, green innovation is not statistically significant in reducing CO ₂ emissions.

countries have been selected randomly based on data availability, focusing on low-middle and upper-middle-income countries (see Appendix 1). Studying these countries can guide other countries on green growth and institutional quality towards low carbon dioxide emissions in other countries. The Worldwide World Bank Development Indicators Database (2023) provided the data for CO₂ emissions as a proxy for environmental sustainability. Institutional quality variables (i.e. rule of law, regulatory quality, control of corruption, voice and accountability, political stability, and government effectiveness) were obtained from the Worldwide Governance Indicators (2023). Green growth index score data was obtained from Sarkodie et al. (2023) which is a compilation from the Economic Cooperation and Development database (OECD, 2023), https://stats.oecd.org/Index.aspx?DataSetCode=GREEN_GROWTH. Green growth index covers five dimensions: natural resources base, socio-economic outcomes, environmental productivity, quality of life, and environmental-related policy responses (see Sarkodie et al., 2023).

A score of 0 implies low green growth, while a score of 1 refers to high green growth performance. Other explanatory and control variables, such as government expenditure, labour force participation rate, gross capital formation, and interest rates data, were also extracted from the World Bank Development Indicators Database (2023). Table 2 demonstrates the variables, and their units of measurement used in this study.

Fig. 1 below shows the map of 40 selected countries in five regions, including Asia, Europe, Latin America, Africa and Oceania.

3.2. Model and estimation techniques

Quantile regression is a statistical technique which estimates different points in the distribution of the dependent variable rather than just its mean (see Byaro et al., 2024). For example, it provides how independent variables affect the median (50th percentile) and other quantiles, such as the 25th or 75th percentiles. This technique helps to understand how relationships of variables may vary across different data segments. The Method of Moments Quantile (MM-QR) regression is among the statistical techniques used to estimate quantile regression by employing the method of moments that involves sample moments such as means and variance to estimate population parameters.

Table 2 Selected variables and their units of measurement.

Variable name	Units of measurement
1. Carbon dioxide (CO ₂)	Metric tons per capita
2. Green growth (GEG) index	Score (0–1)
3. Labour force participation (LF)	Ages 15–64 (% of the total population)
4. Gross fixed capital formation	% of GDP
5. Institutional quality (rule, political, quality, etc), IQ	Estimate using PCA
6. Real interest rates, RE)	% of GDP
7. General government expenditure (GE)	Final consumption expenditure (\$ current)

Note: PCA = Principal Component Analysis.

This study employed Machado and Santos Silva (2019) Method of Moments Quantile regression (MM-QR) with fixed effects for several reasons. First, this approach is useful when the panel data involves endogenous independent variables and individual fixed effects. Second, it can handle non-linearity issues between green growth and institutional variables on carbon emissions. Third, it is less sensitive to outliers than other mean regression models. This means that the method focuses mainly on specific quantiles rather than the mean. While other regressions, such as Autoregressive Distributed Lag (ARDL) and Ordinary Least Squares (OLS), provide a single estimate for the mean, quantile regression explains how the independent variables vary across different points in the dependent variable distribution, such as in lower and upper quantiles (Byaro et al., 2024). Lastly, the MM-QR method is ideal for analyzing complex datasets where relationships may not be linear or normally distributed.

The conditional quantile for location-scale variance can be expressed in the following equations:

$$Y_{it} = \alpha_i + \beta X'_{it} + (n_i + \theta'_{it}\gamma)\mathcal{E}_{it} \tag{1}$$

Where the expression $(n_i + \theta'_{it}\gamma) > 0$ indicates probability of 1 and \mathcal{E}_{it} = independent and identically unobserved random variable distributed across individuals and orthogonal to X'_{it}

Y_{it} = dependent variable (CO₂ emissions as a proxy for environmental quality), X'_{it} = is a vector of endogeneous explanatory variables such as green growth, institutional quality index, financial development, labour force participation, real interest rate, government expenditure and capital formation for each country i with time t . i = country fixed effects. The symbols $(\alpha, \beta, n, \gamma)$ indicate parameters estimates. θ' is a vector of components X'_{it} that satisfy moment conditions $E(U) = 0$, and $E(|U|) = 1$

Therefore, Eq. (1) for conditional quantile coefficient becomes:

$$QY_{it}(\tau|X'_{it}) = (\alpha_i + n_i q(\tau)) + \beta X'_{it} + \theta'_{it}\gamma q(\tau) \tag{2}$$

Where $QY_{it}(\tau|X'_{it})$ denotes the quantile distribution of the dependent variable Y_{it} , and τ demonstrate the τ^{th} quantile range estimates starting at quantiles (10th to 90th). The quantile distribution of the independent variables X'_{it} is shown by $(\tau|X'_{it})$ and show the condition on the location of the independent variables. Likewise, the scale coefficient is represented by $\beta X'_{it} - \alpha_i(\tau) \equiv (\alpha_i + n_i q(\tau))$, which show the quantile of fixed effect.

The study transformed Eq. (2) into linear form and includes the variables as follows:

$$CO_{2it}(\tau|X'_{it}) = \alpha_i + \beta_1^{\tau} GREG_{it} + \beta_2^{\tau} IQ_{it} + \beta_3^{\tau} RIR_{it} + \beta_4^{\tau} LFP_{it} + \beta_5^{\tau} GE_{it} + \beta_6^{\tau} CF_{it} \tag{3}$$

Where α_i = non-addictive fixed effects

CO₂ = Carbon dioxide emissions.

GREG = Green growth.

IQ= Institutional quality index.

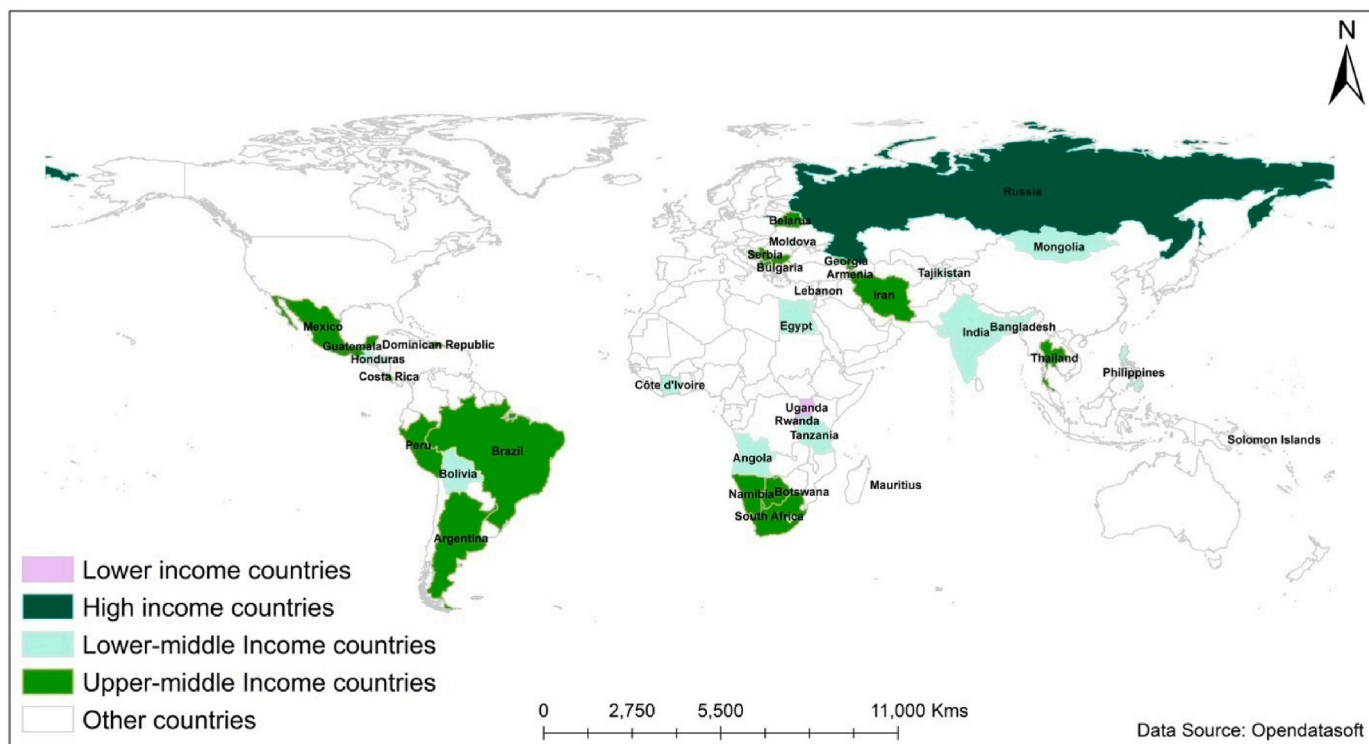


Fig. 1. Map of the international sample of 40 countries included in the study.

RIR= Real interest rate proxy for financial development.

LFP= Labor force participation rate.

GE = Government expenditure.

CF= Capital Formation.

$\beta_1 \dots \dots \beta_6$ = Coefficients of explanatory variables, including control variables.

The reason for including control variables and their justification, such as government expenditure (Kwakwa, 2022; Warsame et al., 2024), capital formation (Maulidar et al., 2024), real interest rates (Isiksal et al., 2019) and labour force participation rate (Maulidar et al., 2024), in the regression model is that all are essential variables influencing economic growth, which, in turn, may affect CO₂ emissions. Similarly, interest rates are related to CO₂ emissions. Lower interest rates can reduce the cost of borrowing, making it more feasible for businesses and governments to invest in clean technologies, which can decrease CO₂ emissions. Overall, government expenditure, capital formation, interest rates, and labor participation rates are included in carbon emissions regression models due to their significant impacts on environmental outcomes and economic activities.

4. Results

Table 3 summarizes descriptive statistics of variables for the selected 40 countries in a full international sample prior to the logarithmic transformation. The median for green growth for many countries is 0.50. Score 1 implies high green growth countries performance, while score 0 implies low green growth performance. Bangladesh is among the countries with a higher green growth performance score of 1. The median estimate for the institutional quality index is -0.46. The median for CO₂ emissions is 1.89. Countries with higher CO₂ emissions are Russia and South Africa.

We tested for correlation analysis to examine whether multicollinearity exists among the variables. Table 4 indicates that there is no multicollinearity, as the coefficient between the two explanatory variables is below 0.8. In addition, we tested multicollinearity using the variance inflation factor (VIF), and the VIF of all explanatory variables is

Table 3

Descriptive statistics summaries.

Variables	N	Mean	Median	Min	Max
Green growth (GREG) index	880	0.49	0.50	0.083	1
CO ₂ emissions	880	2.81	1.89	0.052	11.88
Institutional Quality (IQ) index	880	-6.31 × 10 ¹⁰	-0.046	-2.06	2.45
Labour force participation (LFP)	880	61.42	60.85	39.99	88.35
Government expenditures (GE)	880	3.41 × 10 ¹⁰	5.26 × 10 ⁹	1.28 × 10 ⁸	3.62 × 10 ¹¹
Gross Capital Formation (CF)	880	24.02	23.19	5.35	58.15
Real interest rates	880	6.54	5.68	-34.74	48.50

Source: Authors computation (2024)

less than 2, thus indicating no multicollinearity. To address cross-sectional dependency, Driscoll-Kraay standard errors are employed as a robustness test (see Table 7). The estimator is useful for cross-sectional dependency (Driscoll & Kraay, 1998).

The second task was to examine whether green growth exerts a non-linear impact on environmental sustainability (i.e. CO₂ emissions). Table 5 shows that green growth reduces CO₂ emissions in all quantiles, and the results do not indicate a non-linear relationship. Its impact is very strong and statistically significant across the 10th to 60th quantiles. This means that green growth supports the transition from fossil fuels to renewable energy sources such as solar, wind, hydropower and geothermal energy. This shift reduces dependence on carbon-intensive energy sources and lowers CO₂ emissions. Table 5 also shows the median countries represented by the 50th quantile. This means that in a full sample of 40 countries, green growth reduces carbon emissions, while institutional quality increases carbon emissions. Similarly, the mean coefficient indicates that green growth reduces carbon emissions, while institutional quality raises carbon emissions.

The third task was to examine whether institutional quality exerts a

Table 4
Correlation matrix of variables.

	CO ₂ emissions	Green growth	Government expenditure	Interest rate	Capital formation	Institutional quality index
CO ₂ emissions	1.00					
Green growth	-0.06	1.00				
Government expenditure	0.37	0.10	1.00			
Interest rate	-0.23	0.12	-0.18	1.00		
Capital formation	0.08	-0.05	-0.06	0.02	1.00	
Institutional quality index	0.25	-0.05	0.01	-0.07	-0.07	1.00

Table 5
Method of Moment quantile regression estimates for CO₂emissions (full sample countries).

Variables	Quantiles									Mean	Variance
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	Location effect	Scale effect
Green growth	-0.45** (0.2)	-0.37** (0.2)	-0.31** (0.1)	-0.23** (0.1)	-0.18** (0.1)	-0.15** (0.1)	-0.12 (0.1)	-0.08 (0.1)	-0.03 (0.1)	-0.22** (0.1)	0.13* (0.1)
Institutional quality	0.40*** (0.1)	0.37*** (0.1)	0.35*** (0.1)	0.30*** (0.0)	0.28*** (0.0)	0.27*** (0.0)	0.25*** (0.0)	0.24*** (0.0)	0.22*** (0.0)	0.30*** (0.0)	-0.06** (0.0)
Labor participation	-2.44*** (0.4)	-2.41*** (0.3)	-2.38*** (0.3)	2.35*** (0.2)	-2.33*** (0.2)	-2.32*** (0.2)	-2.30*** (0.2)	-2.29*** (0.2)	-2.27*** (0.2)	-2.35*** (0.2)	0.05(0.1)
Real interest rates	-0.14** (0.1)	-0.13** (0.0)	-0.14*** (0.0)	-0.14*** (0.0)	-0.14*** (0.0)	-0.15*** (0.0)	-0.15*** (0.0)	-0.15*** (0.0)	-0.16*** (0.0)	-0.15*** (0.0)	-0.01 (0.0)
Capital formation	0.20 (0.2)	0.26(0.18)	0.31** (0.15)	0.39*** (0.12)	0.43*** (0.11)	0.45*** (0.11)	0.48*** (0.11)	0.51*** (0.11)	0.56*** (0.12)	0.39*** (0.12)	0.11 (0.08)
Govern. expenditure	0.29*** (0.04)	0.26*** (0.03)	0.24*** (0.02)	0.22*** (0.02)	0.20*** (0.01)	0.19*** (0.01)	0.18*** (0.01)	0.17*** (0.01)	0.15*** (0.02)	0.21*** (0.02)	0.04*** (0.01)
Constant	-1.08	0.76	2.58	3.31**	3.80***	4.36***	5.01***	5.67***	5.78***	3.31**	2.22**
(N)	735	735	735	735	735	735	735	735	735	735	735

Note: Robust standard errors in parentheses (). The notation *, **, and *** show significance at 10 %, 5 %, and 1 % levels respectively with ***p < 0.01, **p < 0.05, and *p < 0.1.

Source: Authors estimation (2024).

non-linear impact on environmental sustainability (i.e. CO₂ emissions). **Table 5** demonstrates that the institutional quality index increases CO₂ emissions in all quantiles. Weak institutions cannot enforce environmental laws, and it allows industries to emit higher carbon emissions without facing penalties. As a result, countries with lower governance indicators tend to have higher pollution levels due to inefficient enforcement of environmental laws. The results show that real interest rates reduce CO₂ emissions in all quantiles. Lower real interest rates stimulate investments in green technologies. For example, companies can invest in renewable energy sources such as solar or wind energy instead of fossil fuels when they borrow at lower costs. This shift is crucial because the transition to renewable energy significantly reduces CO₂ emissions.

Table 5 presents the impact of other variables on CO₂ emissions. It shows that labour force participation has a negative and statistically significant impact on reducing CO₂ emissions across all quantiles. This means a well-educated workforce can lead to more efficient energy use and a shift towards greener technologies (Li et al., 2023). In other words, a well-educated workforce tends to be more aware of environmental issues and sustainable practices. Education provides individuals with knowledge about the impacts of carbon emissions and encourages them to adopt cleaner technologies (Shao et al., 2024). The results also reveal that government spending and gross investment increase CO₂ emissions across all quantiles.

The result in **Table 5** demonstrates that government spending has a significant positive impact on CO₂ emissions in all quantiles. It implies that government expenditure influences economic growth. For example, when governments invest in infrastructure projects such as roads, bridges and public transport systems, they often stimulate economic activity, which in turn increases CO₂ emissions. It is essential to recognise that while government spending stimulates economic growth and improves living standards, it also has the potential to significantly increase CO₂ emissions if not balanced with sustainable practices and

environmental goals.

Table 5 presents that capital formation increases CO₂ emissions in all quantiles. Capital formation is an economy’s capital stock, which is accumulated through investments in physical assets such as machinery, infrastructure and buildings. It means rapid economic growth, driven by heavy investment in infrastructure, is leading to increased demand for energy and resources, which in turn further exacerbates CO₂ emissions.

The robustness test in **Table 6** confirms the quantile regression results in **Table 5**. **Table 6** indicates that green growth reduces CO₂ emissions, although the reduction is not statistically significant. Likewise, the average marginal coefficients of the institutional quality index, capital formation, and government spending have statistically positive effects on increasing CO₂ emissions. On the other hand, we dropped capital formation from the regression model and ran Driscoll-Kraay standard errors for an additional robustness check.

Table 7 shows the results of Driscoll-Kraay standard errors. Driscoll-Kraay standard errors is a robust covariance matrix estimator used in panel data when dealing with heteroskedasticity (non-constant variance), autocorrelation (correlation of residuals over time), and cross-sectional dependence (correlation between different entities). The estimator is useful for cross-sectional dependency (Driscoll & Kraay, 1998). **Table 7** confirms the robustness of the results, showing that green growth, labour force participation and real interest rates reduce CO₂ emissions. In contrast, the institutional quality index increases CO₂ emissions.

4.1. Results for sub-country sample analysis

We further split the sample of 40 countries into sub-sample analyses, including low-middle income (17 countries) and higher-upper income (23 countries), to examine whether green growth and institutional quality continue to matter in preserving environmental sustainability, specifically in reducing CO₂ emissions. **Table 8** demonstrates an analysis

Table 6
Robustness test using KRLS for CO₂ emissions (full sample countries).

Variables	Marginal average	Standard error	25th percentiles	50th percentiles	75th percentiles
Green growth	-0.11	0.07	-0.48	-0.04	0.25
Institutional quality	0.26***	0.03	0.14	0.33	0.78
Labor participation	-2.08***	0.19	-4.03	-1.86	0.23
Real interest rates	-0.12***	0.03	-0.35	-0.12	-0.11
Capital formation	0.43***	0.09	0.33	0.30	1.12
Government expenditure	0.33***	0.02	0.07	0.27	0.54
R ²	0.78				
(N)	735				
Lambda	0.26				

Notation *** shows significance at 1 % levels respectively with ***p < 0.01.

Table 7
Additional robustness check using Driscoll-Kraay standard errors (full sample countries).

Explanatory variables	Dependent variable: CO ₂			
	Coefficient	Standard error.	t	P > t
Green growth	-0.23*	0.14	-1.69	0.09
Institutional quality index (IQ)	0.31***	0.07	4.24	0.000
Government expenditure	0.22***	0.01	17.46	0.000
Interest rate	-0.15***	0.04	-4.18	0.000
Labor force participation	-2.35***	0.23	-10.26	0.000
Constant	4.00	0.70	5.68	0.000

Number of observations = 735, R-squared = 0.33, Maximum lag: 8.
The notation * and *** show significant at 10 % and 1 % levels, respectively, with ***p < 0.01, and *p < 0.1.

of the 17 sub-sample countries classified as lower and lower-middle-income groups. The finding shows that green growth continues to reduce CO₂ emissions and improve environmental sustainability across all quantiles. The coefficients of green growth on CO₂ emissions are significantly negative in most quantiles. The results also show that the institutional quality index in the low and low-middle-income group continues to increase CO₂ emissions, specifically in the upper quantiles across the 70th and 90th percentiles.

On the other hand, Table 9 demonstrates the impact of green growth and institutional quality on environmental sustainability in high and upper-middle-income groups. The results show that most countries in the groups (i.e. median countries at the 50th percentile) indicate the

Table 8
Method of Moment quantile regression estimates for CO₂ emissions in lower-middle-income countries (17 sub-sample countries).

Variables	Quantiles									Mean	Variance
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	Location effect	Scale effect
Green growth	-0.38 (0.3)	-0.40 (0.3)	-0.42* (0.2)	-0.45** (0.2)	-0.48*** (0.2)	-0.49*** (0.2)	-0.51*** (0.2)	-0.52*** (0.2)	-0.54*** (0.2)	-0.46** (0.2)	-0.05 (0.1)
Institutional quality	-0.02 (0.2)	0.01(0.1)	0.03(0.1)	0.06(0.1)	0.09(0.1)	0.11(0.01)	0.12** (0.1)	0.15*** (0.1)	0.17*** (0.1)	0.08(0.1)	0.06(0.01)
Labor participation	-1.69*** (0.5)	-1.68*** (0.5)	-1.66*** (0.4)	-1.63*** (0.4)	-1.60*** (0.3)	-1.59*** (0.3)	-1.58*** (0.3)	-1.56*** (0.3)	-1.55*** (0.3)	-1.62*** (0.3)	0.04(0.2)
Real interest rates	-0.29** (0.1)	-0.26** (0.1)	-0.23** (0.1)	-0.17** (0.1)	-0.11* (0.1)	-0.09 (0.1)	-0.06 (0.1)	-0.02 (0.05)	0.01(0.1)	-0.13** (0.1)	0.10** (0.0)
Capital formation	0.16(0.2)	0.24(0.2)	0.31(0.2)	0.44** (0.2)	0.56*** (0.2)	0.60*** (0.2)	0.65*** (0.2)	0.74*** (0.2)	0.81*** (0.2)	0.50*** (0.20)	0.21** (0.1)
Govern. expenditure	0.34*** (0.1)	0.28*** (0)	0.23*** (0)	0.13*** (0)	0.05(0.0)	0.01(0.03)	-0.02 (0.0)	-0.08** (0)	-0.13*** (0)	0.09** (0)	-0.15*** (0)
Constant	-2.48	-1.28	-0.17	1.76	3.52**	4.26**	4.97***	6.29***	7.45***	2.65	3.29**
(N)	334	334	334	334	334	334	334	334	334	334	334

Note: Robust standard errors in parentheses (). The notation *, **, and *** show significant at 10 %, 5 %, and 1 % levels respectively with ***p < 0.01, **p < 0.05, and *p < 0.1.

Source: Authors' estimation (2025).

positive impact of green growth in increasing CO₂ emissions. The finding implies that high-income countries have not sufficiently decoupled their CO₂ emissions from GDP growth to the point that the rate of decline is very low. The findings suggest that green growth in high and upper-income countries is insufficient to reduce CO₂ emissions, as these countries have economies that rely heavily on fossil fuels and industrial processes, which emit high levels of CO₂. Vogel and Hicel (2023) argued that for high-income countries to achieve CO₂ emissions reduction, it would take an average of more than 220 years to reduce their emissions by 95 percent. While many middle-income countries still rely on fossil fuels, it remains uncertain whether green growth can reduce CO₂ emissions in high-middle-income countries. Our results align with those of Vogel and Hicel (2023), who state that green growth has not performed well in high-income countries and is unlikely to be achieved in the future in terms of carbon reduction.

Moreover, the findings report that institutional quality affects CO₂ emissions positively and significantly across the 70th and 90th quantiles, regardless of the countries' income levels. However, the magnitude of the institutional quality coefficients to increase CO₂ emissions is greater in low- and middle-income countries than in high- and upper-income countries because the latter have stricter environmental regulations than the former. Overall, the impact of green growth on environmental sustainability depends on the country's income levels. In contrast, the impact of institutional quality on environmental sustainability is not dependent on a country's income levels.

5. Discussion of results

This study examines the impact of green growth and institutional quality on CO₂ emissions using a full panel sample of 40 countries, and a

Table 9
Method of Moment quantile regression estimates for CO₂ emissions in upper-middle-income countries (23 sub-sample countries).

Variables	Quantiles									Mean	Variance
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	Location effect	Scale effect
Green growth	0.05 (0.1)	0.06(0.01)	0.08(0.1)	0.09(0.1)	0.12*(0.1)	0.13** (0.1)	0.15** (0.1)	0.16** (0.1)	0.19** (0.1)	0.12** (0.1)	0.05(0.0)
Institutional quality	-0.05 (0.0)	-0.04 (0.0)	-0.01 (0.0)	0.001(0.0)	0.02(0.0)	0.04(0.0)	0.05** (0.0)	0.07** (0.0)	0.10*** (0.0)	0.02(0.0)	0.05*** (0.1)
Labor participation	-2.04*** (0.2)	-2.04*** (0.2)	-2.03*** (0.2)	-2.02*** (0.1)	-2.01*** (0.1)	-2.00*** (0.1)	-1.99*** (0.1)	-1.98*** (0.2)	-1.97*** (0.2)	-2.01*** (0.1)	0.02(0.1)
Real interest rates	-0.15*** (0.0)	-0.16*** (0.0)	-0.17*** (0.0)	-0.18*** (0.0)	-0.20*** (0.0)	-0.21*** (0.0)	-0.22*** (0.0)	-0.23*** (0.0)	-0.25*** (0.2)	-0.20*** (0.0)	-0.03** (0.0)
Capital formation	0.23** (0.1)	0.20*(0.1)	0.16*(0.1)	0.11(0.1)	0.06(0.1)	0.03(0.1)	-0.01 (0.1)	-0.04 (0.1)	-0.10 (0.1)	0.05(0.1)	-0.14** (0.1)
Govern. expenditure	0.15*** (0.0)	0.16*** (0.0)	0.16*** (0.0)	0.16*** (0.0)	0.16*** (0.0)	0.17*** (0.0)	0.17*** (0.0)	0.17*** (0.0)	0.18*** (0.0)	0.17*** (0.0)	0.01** (0.0)
Constant	5.13***	5.26***	5.37***	5.53***	5.68***	5.80***	5.93***	6.04***	6.24***	5.62***	0.20
(N)	401	401	401	401	401	401	401	401	401	401	401

Note: Robust standard errors in parentheses (). The notation *, **, and *** show significant at 10 %, 5 %, and 1 % levels respectively with ***p < 0.01, **p < 0.05, and *p < 0.1.

Source: Authors' estimation (2025).

sub-sample analysis splitting the countries into low-middle and high-upper income countries. The results indicate that green growth reduces CO₂ emissions across all quantiles for the full panel sample, and this effect becomes more significant between the 10th and 60th quantiles. It suggests that countries that encourage the use of green growth strategies, such as transitioning to renewable energy sources like wind, solar and hydropower, help to reduce emissions (Hao et al., 2023; Huang, 2023; Kabiru et al., 2023; Tan & Cao, 2023; Udeagha & Ngepah, 2023; Zhao, Samour, et al., 2023). A full sample analysis suggests that promoting cleaner technologies and sustainable energy systems innovations to support green growth reduces carbon intensity. These findings may also indicate that green growth promotes environmental sustainability by conserving natural resources, thereby preventing pollution and environmental degradation.

Researchers have identified green growth as a key mechanism for reducing CO₂ emissions through various channels. For example, promoting eco-innovation in renewable energy technologies is highlighted as an effective strategy to reduce CO₂ emissions (Khan et al., 2024). The restructuring of industries towards more sustainable practices is another important mechanism. By adopting low-carbon technologies, optimizing the use of resources and creating green jobs, industry contributes to a more sustainable economy while reducing CO₂ emissions. Another important mechanism for countries to ensure green growth is to focus on the transport sector. For example, electric vehicles (EVs) can reduce carbon emissions from road transport. Similarly, promoting public transportation is more important than relying on personal vehicles. Public transport carries many passengers simultaneously, reducing the number of vehicles on the road and thereby reducing congestion while providing an ideal platform for integrating green technologies, such as electric buses. It will help reduce dependence on fossil fuel consumption while maintaining stable economic growth.

Overall, investing in infrastructure that supports low-carbon technologies, such as public transportation systems powered by renewable energy, can help countries dramatically reduce their carbon footprint (Alnour et al., 2024; Kwilinski et al., 2024). Targeted public spending on initiatives in environmental protection and programs to reduce pollution and improve energy can also support the transition to a green economy (Chen & Li, 2024).

It is important to note that the effectiveness of these measures may vary from country to country. For example, our findings show that green growth reduces CO₂ emissions in low- and middle-income countries while increasing it in high-upper-middle-income countries. These results suggest that green growth strategies are more effective in low- and middle-income countries. Studies have shown that greater

environmental policy regulations and green growth initiatives in middle-income countries significantly reduce CO₂ emissions (Demiral et al., 2021). In contrast, high-income countries show less evidence of decoupling economic growth from emissions, mainly when consumption-related emissions are considered (Knight & Schor, 2014). The higher potential for reducing CO₂ emissions in low- and middle-income countries through green growth is likely due to their ongoing structural changes towards more industrialized economies, offering opportunities to build green infrastructure from the ground up rather than retrofitting existing systems (Sohag et al., 2017). Moreover, low-and middle-income countries often have cheaper land and labour costs, which makes green investments more cost-effective (Glennester & Jayachandran, 2023).

The results also reveal that institutional quality has a positive and statistically significant effect on CO₂ emissions across all quantiles. The findings are consistent across the full sample of 40 countries and the sub-sample analysis. In the context of weak governance, governments in various countries often fail to enforce and respect environmental regulations, and they also fail to hold individuals accountable for their emissions (Yuan et al., 2021). These findings imply weaker institutions are associated with higher emissions (Bekun et al., 2021). It is also important to note that better institutions may lead to higher emissions, possibly due to increased economic activity. The fact that institutional quality increases carbon emissions in low- and high-income countries leads to counterintuitive results that are also attributable to other factors. High-quality institutions, characterized by a strong rule of law and effective governance, for example, tend to promote economic growth and industrialization. This growth, in turn, encourages more production and consumption, which are the leading cause of greenhouse gas emissions.

Improved institutions can also promote high economic growth by making transactions more efficient. This rapid growth may lead to increased demand for energy and manufacturing, resulting in higher carbon emissions. Similarly, a high-quality institution enhances overall governance, which tends to favour economic development over environmental protection, leading to higher carbon emissions. In turn, these high emissions attract stricter environmental regulations.

Several studies have shown that institutional quality may unexpectedly increase CO₂ emissions in specific contexts. For example, Wen et al. (2022) found that in G20 countries, indicators of governance quality increased carbon emissions, contrary to expectations. Similarly, high government effectiveness in emerging and developing countries is associated with higher CO₂ emissions (Wawrzyniak & Doryń, 2020). Cooray and Özmen (2024) found that stronger institutions, such as the

European Union, increased carbon emissions. Although many studies show that higher institutional quality reduces CO₂ emissions (Khan & Rana, 2021; Kwakwa, 2023; Murshed, 2024; Sajid et al., 2024; Zheng et al., 2024), this study suggests that institutional quality in high-upper-middle and low-middle-income countries are associated with increased emissions, possibly due to factors such as economic growth or industrialization.

Overall, our findings are consistent with previous studies that claimed institutional quality, such as corruption, environmental regulations and efficient government structures, affects environmental pollution and increases carbon emissions (Abid, 2017; Acheampong & Said, 2024; Dam et al., 2024; Fredriksson & Svensson, 2003; Obobisa et al., 2022). Lau et al. (2014) suggested that to reduce carbon emissions and improve environmental performance, governments need to strengthen the role of institutional quality by improving governance and regulatory frameworks. The main mechanisms influencing institutional quality failure to reduce carbon emissions in the countries studied could be a poor regulatory framework and law enforcement. These factors indicate that regulations and laws are poorly enforced and inadequately designed, thereby encouraging practices that contribute to higher carbon emissions. For example, the absence of a regulatory framework may mean that many industries can operate without environmental restrictions, resulting in higher CO₂ emissions. Another mechanism is corruption and mismanagement. When officials are involved in corruption scandals, it leads to a lack of accountability and mismanagement, resulting in relaxed regulations and higher carbon emissions.

The results also show that real interest rates reduce CO₂ emissions, with a statistically significant impact across all quantiles. Financial institutions provide the necessary financing for projects aimed at reducing carbon emissions. By offering favourable loan terms such as lower interest rates or longer repayment terms, financial institutions can encourage companies to invest in renewable energy sources, energy-efficient technologies and other sustainable practices. These actions support the notion that lower borrowing costs stimulate investment in green technologies, enabling firms to adopt more sustainable practices. These actions also suggest that a low-carbon economy can be achieved when financial development aligns with environmental goals (Orazio, 2022, pp. 7678–7702).

The findings also reveal that labour force participation has a negative impact on CO₂ emissions across all quantiles. The findings also suggest that greater worker engagement and training on environmental protection and sustainable use of natural resources can contribute to lower carbon emissions. Therefore, on-the-job training can enhance a better understanding of environmental sustainability. The study findings are consistent with previous studies supporting the notion that an educated workforce promotes environmental sustainability (Achuo et al., 2023; Naseer et al., 2022; Wang et al., 2021; Zhong & Su, 2021).

The findings indicate that government spending and capital formation have a positive impact on increasing CO₂ emissions across all quantiles. These findings suggest that when governments allocate funds to economic growth and infrastructure development, they inadvertently contribute to environmental degradation by increasing energy consumption and resource consumption. For instance, large-scale construction projects may increase economic activity and, hence, lead to more carbon emissions. Our study findings are consistent with those of Khan and Rana (2021), who stated that more public spending tends to stimulate more economic activity, which in turn, reduces environmental quality.

6. Conclusion and policy implications

This study examines the impact of green growth and institutional quality on environmental sustainability, specifically on CO₂ emissions, using an international panel sample comprising 40 countries from 2000 to 2021. For the analysis, the study divided the full panel sample of 40 countries into low- and middle-income countries (17 countries) and

high- and upper-income countries (23 countries) to observe whether green growth and institutional quality have different impacts on environmental sustainability across country's income levels. The study controlled the labor force, capital formation and government spending in the model. To generate reliable results, the study employed the Method of Moment Quantile regression (MM_QR), KRLS, and Driscoll-Kraay standard errors for a robustness check.

The results indicate three main findings: i) For a full panel sample of 40 countries, green growth reduces CO₂ emissions. ii) For the sub-sample analysis, green growth reduces CO₂ emissions in low- and middle-income countries but does not contribute to the reduction of CO₂ emissions in high- and upper-income countries. iii) For a full panel sample analysis, institutional quality increases CO₂ emissions. Similarly, in the case of sub-sample analysis, both low-middle and high-upper-income countries lead to an increase in CO₂ emissions. The fact that institutional quality increases CO₂ emissions highlights the crucial role of governance in environmental management. Countries with poor institutional frameworks struggle to impose environmental regulations, which in turn lead to higher levels of emissions.

On the other hand, our results align with the Green Solow Model theory that green growth reduces CO₂ emissions and enhances environmental sustainability. Achieving low carbon emissions through green growth requires multiple stakeholders (such as government, industry, businesses, non-governmental organizations and international cooperation (i.e. a full panel sample from 40 countries). However, high- and upper-income countries have not decoupled their CO₂ emissions efficiently from GDP growth, so the rate of decline has been very slow. This suggests that green growth in high- and middle-income countries is not well geared to carbon reductions.

Overall, this study provides two key conclusions. First, the impact of green growth on CO₂ emissions depends on the country's income levels. Second, the impact of institutional quality on CO₂ emissions is not dependent on a country's income levels. The study recommends that high-upper middle-income countries should transition to green growth initiatives, such as investing in low-carbon technologies and sustainable business practices to help reduce their CO₂ emissions. Low- and middle-income countries should continue to strengthen their policy frameworks to promote long term green growth to reduce carbon emissions. On the other hand, the policy implications underscore the need to enhance institutional quality in high- and upper-middle, and low-middle-income countries to improve environmental regulations and effectively enforce environmental laws and other related policies that minimize CO₂ emissions and achieve environmental sustainability.

To implement the highlighted recommendations, countries require financial incentives, such as grants and subsidies, to encourage greater investment in green technologies and green projects. Similarly, investments in research and development (R&D) for green technologies are beneficial in both low- and middle-income countries as well as high-income countries. International cooperation is needed to provide funding for universities and research institutes specializing in green innovation. In addition, engagement with companies, communities, investors and employees is crucial to support initiatives for environmental sustainability in both high- and low-income countries.

This study included only 40 countries to represent an international sample from each continent, but it has limitations. The main limitation of the study is that it focuses on a full panel of 40 countries, chosen to represent each region, with a concentration primarily on high-upper-middle and low-middle-income countries while excluding the largest emitters of CO₂ emissions, such as the US, Canada, China, the UK and Germany. Another limitation is that CO₂ emissions are linked to several factors, such as renewable energy, population size, urbanization, trade and industrialization, which are not taken into account. Future studies should consider these variables and divide the selected countries into two groups: those with high and low governance quality. This approach will provide further insight into the impact of green growth and institutional quality on CO₂ emissions while employing other econometric

methods.

CRedit authorship contribution statement

Mwoya Byaro: Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Monica Timbuka:** Writing – review & editing, Writing – original draft, Supervision, Investigation, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1. List of countries based on income levels

Low-Income Countries:
Rwanda Uganda
Lower-Middle-Income Countries
Tanzania Angola Bangladesh Bolivia Cote d'Ivoire Egypt, Arab Rep. Guatemala Honduras India Lesotho Moldova Mongolia Philippines Solomon Islands Tajikistan
High-Income Countries
Russian Federation
Upper-Middle-Income Countries
Costa Rica Malaysia Mauritius Mexico Albania Argentina Armenia Belarus Botswana Brazil Bulgaria Dominican Republic Georgia Iran, Islamic Rep. Jamaica Lebanon Namibia North Macedonia Peru Serbia South Africa Thailand

Source: <https://blogs.worldbank.org/en/opendata/world-bank-country-classifications-by-income-level-for-2024-2025>

Availability of data and materials

World Bank Development Indicators (2023). <https://databank.worldbank.org/source/world>.

Worldwide Governance Indicators (2023). <https://databank.worldbank.org/source/worldwide-governance-indicators>. Green growth index score obtained from <https://doi.org/10.6084/m9.figshare.22291069.v2>

Funding

The study reports no source of funding

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