*Lahore Journal of Economics*
*Volume 30, Issue 2,*
*Winter 2025*

# Financial Development and $CO_2$ Emissions: A Global Analysis and Continent-level Comparisons of Institutional Quality's Mediating Role

**Ayesha Rehman**
*Data Supervisor*
*RASTA- Pakistan Institute of Development Economics, Pakistan*
*(Corresponding author)*
*Email: ayesharehmanqau@gmail.com*
*ORCID ID: 0009-0007-7982-3542*

**Muhammad Tariq Majeed**
*Director & Professor of Economics, School of Economics, Quaid-i-Azam University Islamabad, Pakistan*
*Email: tariq@qau.edu.pk*
*ORCID ID: 0000-0001-9374-5025*

**Tania Luni**
*Research Scholar, School of Economics, Quaid-i-Azam University Islamabad, Pakistan.*
*Email: tania_luni@yahoo.com*
*ORCID ID: 0000-0002-7022-1920*

**Citation:** Rehman, A., Majeed, M.T., and Luni, T. (2025). Financial Development and $CO_2$ Emissions: A Global Analysis and Continent-level Comparisons of Institutional Quality's Mediating Role. *The Lahore Journal of Economics*, *30* (2), 63–98. https://doi.org/10.35536/lje.2025.v30.i2.a3



**Abstract:** This study examines the relationships among financial development, renewable energy, institutional quality, and carbon dioxide (CO2) emissions using dynamic panel data techniques from 1990 to 2020. The empirical results of the econometric analysis suggest that financial development does not necessarily reduce CO2 emissions unless institutional quality improves. Financial development exacerbates environmental deterioration by increasing CO2 emissions in all regions except Europe, whereas renewable energy consumption and institutional quality improve environmental quality. Thus, good institutional quality emerged as a mediating variable between financial development and environmental quality in curbing CO2 emissions and promoting sustainable development worldwide.

Received: 3rd April 2025 Revised: 30th July 2025 Accepted: 19th November 2025

**Keywords:** Carbon dioxide emissions; economic growth, financial development; institutional quality; renewable energy consumption, system GMM.

**JEL Classification:** E31, Q41.

**Paper type:** Research paper

**Conflict of interest:**
The authors declare no conflict of interest.

**Funding:**
There is no funding for this research.

# Financial Development and $CO_2$ Emissions: A Global Analysis and Continent-level Comparisons of Institutional Quality's Mediating Role

## 1. Introduction

The environmental deterioration marked by increased greenhouse gas (GHG) emissions has become an unavoidable global challenge. Among GHGs, carbon dioxide (CO2) is one of the primary contributors to pollution, accounting for at least 75.01% of worldwide emissions (Ritchie et al., 2024) and contributing to adverse climatic conditions. This increase in CO2 emissions and climate change can be attributed to rapid industrialization, deforestation, and the unchecked use of fossil fuels to accelerate economic growth (Chirwa, 2023). To design and implement effective climate strategies, it is essential to understand the interactions among the financial sector, regulatory authorities, and other socio-economic factors, such as economic growth, renewable energy use, population, and industrialization.

Despite a growing body of literature, conflicting results mean that the impact of financial development (FD) on $CO_2$ emissions remains unclear (Azam *et al*., 2019). With several studies supporting positive spillover effects of FD in boosting the economic and ecological prosperity of a nation by research and development, increasing energy efficiency through investment in eco-friendly projects and cleaner technologies (Habiba & Xinbang, 2022; Li *et al*., 2022; Ruan *et al.,* 2023; Cheng *et al.,* 2025), while others highlight the detrimental environmental effects of increased industrial activities and energy intensive devices increasing $CO_2$ emissions in the atmosphere (Jensen, 1996; Zhang, 2011; Shoaib *et al.,* 2020; Sakilu & Chen, 2024). In addition to FD, institutional quality (IQ) plays a pivotal role in addressing environmental challenges through enforcing stringent regulations. Governments with robust institutional frameworks can effectively direct finances towards sustainable energy initiatives such as renewable energy (RE) adoption, technological innovations, and green energy promotion (Trevisan *et al.,* 2023). However, the extent to which IQ moderates the environmental impact of FD remains underexplored. This study aims to bridge this gap by investigating the combined impact of FD and IQ globally and regionally.

The analytical foundation of the study relies on the STIRPAT framework, which extends the IPAT model to quantify the impact of socio-economic and demographic indicators, including population, affluence, and technology, on environmental quality proxied by $CO_2$ emissions. This model rests upon well-grounded theories that provide insight into the real drivers of environmental change. A complementary approach, the Porter Hypothesis, proposed by Porter (1991), holds that strict environmental regulations incentivize firms to adopt cleaner processes and technologies that enhance productivity, reduce costs, and spur innovation. This highlights the critical role of FD in promoting eco-friendly innovations. It mobilizes financial resources to drive innovations such as Fintech (the fusion of finance and technology), which reduces carbon emission intensity by increasing energy efficiency and supporting green finance (Xu *et al.,* 2023; Wang *et al.,* 2024). However, the lack of transparent governance can compromise the benefits of financial flows, leading to increased $CO_2$ emissions.

These theoretical foundations facilitate the selection of potential determinants of environmental quality, such as economic growth (GDP), renewable energy (RE), industrialization, urban population, and trade (Le *et al.,* 2016; Pata, 2018; Azam *et al*., 2022). Most studies focused on the relationship between FD and $CO_2$ emissions, while ignoring the role of IQ (Jiang & Ma, 2019; Habiba & Xinbang, 2022; Udeagha & Breitenbach, 2023). However, a few studies examine the role of IQ alongside FD, but either use a single proxy for FD and IQ or are confined to a specific region (Tamazian & Rao, 2010; Sheraz *et al.,* 2022), thereby ignoring a wider perspective.

This study will contribute to the literature by addressing the following gaps. First, this study uses indices of FD and IQ constructed by including variables that affect FD and IQ. Unlike previous studies, which used only a single proxy for FD and IQ to capture their impact on environmental quality. Second, this study provides evidence for an analysis by continent, as previous research has been clustered around specific regions (Sheraz *et al*., 2022; Adedoyin *et al*., 2022; Vatamanu & Zugravo, 2023). Continent-level analysis provides insights into the regional disparities in resource availability, technological capabilities, and institutional structures, guiding policymakers in implementing targeted interventions in the transition towards a low-carbon economy. Third, the inconclusive effects of FD on $CO_2$ emissions necessitate an interaction term (FD*IQ) to determine whether institutions mitigate the harmful impact of FD on $CO_2$ emissions. Fourth, this study used GMM to address endogeneity, followed by a robustness check using Panel Quantile and Driscoll and Kraay standard error analyses. Driscoll and Kraay's standard error also considers cross-sectional dependence.

This study investigates the following research questions: 1) What is the effect of FD on $CO_2$ emissions? 2) What is the effect of IQ on $CO_2$ emissions? 3) To what extent does IQ moderate the relationship of FD with $CO_2$ emissions, and 4) How does RE contribute to $CO_2$ emissions? and 5) How do these relationships change at the global and continent levels?

The study is structured as follows: Section 2 provides the literature. Section 3 consists of data description and methodology. Section 4 provides results and discussion. Sections 5 and 6 provide robustness analysis and a conclusion.

## 2. Literature Review

### *2.1 Theoretical Underpinnings*

Over the past few decades, the process of industrialization, powered by the utilization of fossil fuels, has fostered breakthrough economic growth. However, these developments have brought radical changes in people's living standards. It adversely affects the quality of life by polluting the atmosphere (Darcin, 2014). To address worsening climate change, global economies are working to curb $CO_2$ emissions.

The association between economic growth and environmental quality has been explored extensively in the literature since the 1970s, following the publication of "The Limits to Growth" by the Club of Rome (Meadows *et al.,* 1972), which advocates a zero-growth or steady-state economy to mitigate environmental risks. Findings across studies yield contrasting results (Bansal, 2014; Sineviciene *et al.,* 2018; Chong *et al.,* 2022). Environmental quality depends on several factors, including scale effects, composition effects, and technique effects. The scale effect describes how the level of economic activity impacts the environment. An increase in industrial activities results in greater use of natural resources, higher energy consumption, and increased GHG emissions, which worsen environmental degradation (Liobikiene & Butkus, 2019). The composition effect indicates a structural change in the economy that is a shift to less carbon-intensive sectors, while technique effects foster technological innovation, leading to a cleaner environment.

FD and environmental degradation are closely linked, as was first noted by Aufderheide & Rich (1988) and Schmidheiny & Zorraquin (1998). They reported that FD leads to environmental decline. They emphasized the role of the World Bank and other multilateral banks, which often overlook environmental factors when disbursing loan funds. They cited evidence from India, where financial aid without environmental safeguards resulted in soil erosion and forest land degradation, particularly due to rubber projects.

The financial sector plays a critical role in the smooth functioning of an economy by disseminating information on funding, monitoring investments, enhancing profits, minimizing risks, accelerating trade, and creating employment opportunities, all of which contribute to a nation's economic growth (Pagano, 1993; Calderon & Liu, 2003). The history of each developed nation shows the presence of strong financial institutions that helped mobilize capital and allocate resources. In this way, FD helps balance growth across all sectors of the economy. FD can both support and deteriorate environmental quality. On one hand, FD stimulates the economy by increasing access to funds that could be invested in clean energy projects (Khan *et al.* 2020, Sun *et al.*, 2023), supporting environmental improvement, while on the other hand, increased energy consumption and production based on fossil fuels can lead to increased $CO_2$ emissions. Possible reasons for these conflicting results include the nature of the data, the measurement method, and regional differences.

The theory of IQ explains the influential role of a nation's institutions in shaping people's economic and social behavior. It consists of a wide set of rules, norms, and values, and guides developing countries to learn from developed nations and to develop appropriate policies that could pave the way to prosperity. Strong government institutions ensure the enforcement of environmental standards, thereby improving environmental quality (Danish & Ulucak, 2020). The role of governance in enhancing the quality of institutions by imposing strict regulatory measures and ensuring transparency helps abate $CO_2$ emissions by redirecting funds to clean energy projects, thereby achieving the SDGs.

Sustainable development theory is defined as "the development that meets the needs of the present without compromising the ability of future generations to meet their needs." It describes the interconnected crises of environment, energy, and development, as well as the insufficiency of current resources. The 2030 Agenda for Sustainable

Development emphasizes reaching goals that support inclusive growth and balanced economic, social, and environmental progress (United Nations, 2015).

Ecological modernization theory states that advanced economies develop institutionalized environmental governance systems that gradually decouple economic activity from ecological effects. Similarly, EKC also states that as the economy grows, environmental conditions deteriorate, but after reaching a certain point, environmental quality begins to improve. Thus, EKC suggests a non-linear relationship between economic development and environmental quality, whereas IPAT assumes a linear increase in environmental impact with increasing population (Majeed & Tauqir, 2020).

### *2.2 FD and $CO_2$ Emissions*

The empirical literature also provides conflicting results regarding the impact of FD and $CO_2$ emissions. The studies of Jiang & Ma (2019), Wang *et al.* (2020), and Qayyum *et al.* (2021) reported an increase in $CO_2$ emissions from FD, while Charfeddine (2017), Kirikkaleli & Adebayo (2020), and Udeagha & Breitenbach (2023) reported a decrease in $CO_2$ emissions from FD. Jiang & Ma (2019) conducted a panel data study of 155 countries, and the results showed that financial growth exacerbates CO2 emissions in developing and emerging economies, while being insignificant for developed nations. It can be attributed to differences in priorities: developing and emerging economies are more inclined to scale up rather than invest in energy-efficient technologies, whereas developed economies prioritize environmental safety. The studies by Wang *et al.* (2020) for N-11 countries and Islam (2022) for South Asia concluded an increase in $CO_2$ emissions from FD. Qayyum *et al.* (2021) also reported a surge in $CO_2$ emissions in India due to the inefficiency of financial institutions that invest in small-scale businesses to generate profits.

Another group of researchers found conflicting results, where FD negatively impacts CO2 emissions on a global and regional scale level. Kirikkaleli & Adebayo (2020) conducted a study on the global economy and found FD to be effective in decreasing $CO_2$ emissions by providing access to loans for investment in environmental protection programs. Udeagha & Breitenbach (2023) explored the direct and indirect impacts of FD on climate change mitigation in South Africa using the Environment Kuznets Curve (EKC) analytical framework. Their results revealed that FD both temporarily and permanently helps reduce $CO_2$ emissions and suggested national interventions to achieve sustainability targets for net-zero $CO_2$ emissions. Similarly, the study of Solaymani & Montes (2024) also reported a decrease in $CO_2$ emissions from FD in New Zealand. FD encourages research and development, provides green loans, and finances energy-efficient projects.

Khan *et al.* (2020) also found similar results for Pakistan, where FD helped in decreasing $CO_2$ emissions. The author suggested adopting efficient national environmental, fiscal, and monetary policies to safeguard the environment. These results are similar to those of Charfeddine (2017) for Qatar, who also advocated designing and implementing efficient environmental policies to combat rising $CO_2$ emissions.

The transition to a low-carbon economy has been supported by the transformative role of Fintech and the Internet of Things (IoT), reshaping the FD paradigm. The digital innovations like e-banking, big data, and blockchain technology ensure financial inclusion, transparency in the stock market, support green economic growth, increase renewable energy adoption, and reduce corporate carbon emissions, paving the path to sustainability (Brem *et al.,* 2016; Croutzet & Dabbous, 2021; Awais *et al.,* 2023; Wang *et al.,* 2024). Similarly, IoT-driven technologies help curb carbon emissions by increasing transparency through real-time data tracking and monitoring (Tsokov & Antonova, 2017; Alpan *et al.,* 2022; Li *et al.,* 2025).

### *2.3 IQ and $CO_2$ emissions*

Strong institutional frameworks can lead to the sustainable use of financial resources, helping to mitigate $CO_2$ emissions. Tamazian & Rao (2010) establish the significance of IQ in reducing $CO_2$ emissions across 24 transitional economies. Their results suggested that efficient financial institutions can lead to environmentally sustainable pathways in the presence of strong regulatory bodies and support the development of clean technologies, thereby reducing environmental degradation. Ibrahim & Law (2016) examined the roles of IQ and trade in a sample of 40 Sub-Saharan African countries and found that institutional reforms were extremely helpful in realizing the benefits of trade and reducing $CO_2$ emissions. Halder & Sethi (2021) investigated the moderating impact of IQ on energy consumption and $CO_2$ emissions across 39 developing countries and found that IQ was helpful in abating emissions, particularly in the residential and transportation sectors. This effective role of IQ can be attributed to strict environmental rules that promote investment in clean energy sources and energy efficiency.

Khan & Rana (2021) conducted a panel data study across 41 Asian countries to measure the direct and indirect effects of IQ on $CO_2$ emissions and found that strong political institutions significantly help reduce $CO_2$ emissions in Asia. A moderating effect of IQ on the negative impacts of income was also detected. This highlights the important role of governance in improving environmental quality. Since economic growth is a key indicator of a country's overall performance, a growth-emissions relationship study for Indonesia, Thailand, and South Korea by Salman *et al.* (2019) also supports the existence of effective domestic institutions that both promote economic growth and encourage green investment to curb $CO_2$ emissions.

A recent study conducted by Vatamanu & Zugravo (2023) shed light on the dynamic relationship between FD and consumption of RE in the presence of institutional variables. The results of this study for 27 European Union (EU) member states confirmed a robust positive relationship between all the variables. The literature also provides contradictory results regarding the relationship between IQ and $CO_2$ emissions. Godil *et al.* (2020) conducted a study for Pakistan, and the results show that IQ increases $CO_2$ emissions. The study suggested restructuring the financial institutions and energy consumption patterns to combat the evils of bad governance and corruption, and improving IQ could help in achieving a sustainable environment.

A comparative study of the European Union (EU) and G-20 members conducted by Dinca *et al.* (2022) revealed a direct positive impact of IQ on increased $CO_2$ emissions in these regions. The authors suggested implementing strict rules and regulations to build public confidence in the government's decisions and using renewable energy resources to enhance environmental performance.

A comprehensive review of the literature also shows RE to be one of the most important contributors to change in $CO_2$ emissions. RE consumption boosts economic growth by protecting the environment from hazardous, poisonous chemicals released during the burning of fossil fuels, thereby encouraging the adoption of clean technology (Magazzino *et al.*, 2022). Thus, the energy transition from 'vulnerable' to 'sustainable' resources is being followed everywhere in the world (Khan *et al*., 2022). The idea of RE-driven sustainable development, emphasizing green growth, has garnered significant attention recently (Usman *et al*., 2020; Khan *et al*., 2023; Zheng *et al*., 2023). RE sources are inexhaustible, cheaper, and environment-friendly, ensure energy security, reduce fossil fuel import dependence, and provide a reliable solution to combating the problems associated with non-RE sources (Chen *et al*., 2022).

Taken together, the divergent findings from the empirical review of FD and IQ on $CO_2$ emissions stem from a variety of reasons, including data coverage, variable inclusion, and methodological differences, but most importantly from regional heterogeneity in economic and institutional structures.

This indicates the need for a thorough analysis of the fundamental causes of carbon emissions. The review of the literature reveals some weaknesses. First, most studies are based on the theoretical framework of EKC, which primarily focuses on economic growth rather than sustainable development. The term 'sustainable development' is a broader concept that involves redirecting investments toward alternative energy sources like renewables, along with institutional reforms that can support green growth and ultimately a sustainable future. Second, many studies assess the impact of FD and IQ on $CO_2$ emissions using proxy variables instead of developing a comprehensive index that encompasses all relevant factors affecting $CO_2$ emissions. Third, only a few studies offer global evidence (Kirikkaleli & Adebayo, 2020; Sun *et al*., 2023). Lastly, a comparative analysis at both the global and continent level is lacking, which could reveal differences masked in the overall global perspective. These variations are influenced by geographical location, natural resource endowments, population size, and cultural or institutional factors.

The current study fills the gap by providing a comprehensive analysis of the impact of FD and IQ on $CO_2$ emissions at the global level and for the continents of Asia, Africa, and Europe by employing panel data techniques from 1990 to 2020. It also measures the combined impact of FD and IQ on $CO_2$ emissions and explains its significance in the context of differences in results across continents. The study also provides evidence about the impact of FD, IQ, and FD*IQ on $CO_2$ emissions across quantiles.

## 3. Data Description and Methodology

### *3.1. Data and Variables Description*

Panel data for 111 countries from 1990 to 2020 are taken from the World Bank (2023), as per the availability of $CO_2$ emissions data. This 31-year span also allows us to consider the major financial, institutional, and environmental reforms across the globe. The disaggregated analysis included 41 Asian, 47 African, and 21 European countries. The selection of variables is based on well-established theoretical and empirical research available in this field. $CO_2$ is widely used as a proxy for environmental degradation (Ehrlich & Holdren, 1971; Xaisongkham & Liu, 2024), whereas FD, IQ, GDP, RE, trade, urban population, and industrialization are used as independent variables in their relevance to the IPAT and STIRPAT model (Dietz & Rosa, 1997). The FD index is constructed following Tahir *et al*. (2021) and Muhoza (2019) using variables such as domestic credit to the private sector (DCP), domestic credit to the private sector by banks (DCPB), and broad money (BM). These indicators reflect the financial intermediation and depth of the financial market. Domestic credit to the private sector measures the support provided by financial institutions to private firms or businesses, while broad money is an indicator of the total money in circulation in the economy. Similarly, an index of IQ is constructed by using six variables, namely control of corruption (COC), political stability (PS), regulatory quality (RQ), rule of law (ROL), government effectiveness (GE), and voice and accountability (VOA) (Ha & Nguyen, 2023). These proxies are used to construct a composite index of financial development and institutional quality via Principal Component Analysis (PCA), which helps capture the true picture of these variables across countries over time and also addresses the problem of multicollinearity (Muhoza, 2019; Tahir *et al*., 2021). The details are provided in Appendix A. The internal consistency of the variables used to construct indices is further verified by calculating Cronbach's Alpha. The reliability scores ($\alpha$=0.97 for FD and $\alpha$=0.96 for IQ) support the use of PCA. An interaction term of FD and IQ (FD*IQ) is also added to test the moderating role of IQ. Table 1 describes all the variables and sources.

**Table 1: Data Description & Source**

| Variable | Abs | Definition/Description | Source | Transformation |
|---|---|---|---|---|
| $CO_2$ emissions | $CO_2$ | Metric tons per capita | World Bank, 2023 | Log |
| **Independent Focused Variables** | | | | |
| Financial development | FD | Index of DCP, DCPB, and BM | World Bank, 2023 | Level |
| Institutional quality | IQ | Index of COC, PS, RQ, ROL, GE and VOA | World Bank, 2023 | Level |
| Interaction Term | $FD^*IQ$ | Product of FD and IQ | Self-constructed | Level |
| **Control Variables** | | | | |
| Economic Growth | GDP | GDP per capita constant 2015 US$ | World Bank, 2023 | Log |
| Renewable Energy | RE | Percentage of final total energy consumption | World Bank, 2023 | Log |
| Trade | TRADE | % of GDP | World Bank, 2023 | Log |
| Urban Population | URB | % of the total population | World Bank, 2023 | Log |
| Industrialization | IND | Industry (including construction), % of GDP | World Bank, 2023 | Log |

### 3.2. *Analytical Framework*

Ehrlich & Holdren (1971) developed the IPAT model to examine how population expansion affects the environment. I represent the environmental impact quantified by taking carbon dioxide as a proxy and three other factors, including population (P), affluence (A), and technology (T), combined to form this identity;

$$I = P_* A_* T$$

To examine the impact of different factors on the environment and function, later researchers, Dietz & Rosa (1997), expanded the STIRPAT model from the initial IPAT version. In this way, $CO_2$ emissions depend on P, A, and T in the following ways;

$$CO_{2it} = aP_{it}^{b}\, A_{it}^{c} T_{it}^{d}\, e_{it} \quad (1)$$

Where $a$ denotes the regression slope coefficient, $i$ the cross-sectional units, and $t$ the time period. Similarly, $b$, $c$, and $d$ denote the elasticity coefficients of P, A, and T. Lastly, $e$ represents the residual. In logarithmic form, the model is rewritten as follows (Equation 2):

$$LCO_{2it} = \alpha_0 + \beta LP_{it} + \gamma LA_{it} + \varphi LT_{it} + \varepsilon_{it} \quad (2)$$

Where *P* is the population proxied by the urban population (Baloch *et al.*, 2019; Ahmad *et al.*, 2020), $A$ is affluence proxied by GDP per capita (Sun *et al.*, 2021), and $T$ is technology proxied by FD (Hafeez *et al.*, 2018; Baloch *et al.*, 2019) and renewable energy.

An increase in urban population increases energy consumption, land usage, and waste generation. This signifies its inclusion in the IPAT framework to analyze its impact on carbon emissions. Industrialization is also a major contributor to rising emissions that cause environmental harm. Increased industrial activity and free trade lead to economic growth, which is usually characterized by strong financial institutions. The role of institutions is crucial for preventing corruption and enforcing strict environmental policies (Danish & Ulucak, 2020; Haldar & Sethi, 2021). Thus, the positive contributions of the financial sector and better governance pave the way for sustainable development. To test the moderating role of institutional quality on $CO_2$ emissions, an interaction term, $FD^*IQ$, has also been added. The extended version of the STRIPAT model can be written as Equation 3:

$$LCO_{2it} = \beta_0 + \beta_1 LGDP_{it} + \beta_2 FD_{it} + \beta_3 IQ_{it} + \beta_4 FD_{it} * IQ_{it} + \beta_5 LRE_{it} + \beta_6 LTRADE_{it} + \beta_7 LURB_{it} + \beta_8 LIND_{it} + \mu_{it} \quad (3)$$

where $CO_2$ are the $CO_2$ emissions, FD represents the FD index, and IQ is the IQ index. All other variables, including GDP, represent economic growth; RE represents RE consumption; TRADE represents trade openness; URB represents urban population; and IND represents industrialization, and are used as control variables in the model. L represents the log-transformed variables. $\beta_0$ and $\mu_{it}$ are, respectively, the intercept and the error term.

The model will assist us in analyzing the quantitative impact of explanatory variables on global $CO_2$ emissions. To gain more insight, the analysis has been split into three independent continents—Asia, Africa, and Europe—to determine which continent would benefit the most from changes to its financial institutions and more effective governance.

### *3.3. Econometric Technique*

Panel data are a convincing option for this research, as they integrate cross-sectional and time-series data. Before investigating the causal relationship between the observed variables, Pesaran (2004) recommends tests for cross-sectional independence, followed by panel unit root tests for stationarity. The analysis proceeds by estimating fixed effects and random effects. The fixed effects estimate individual-specific effects that capture inherent differences among countries that remain stable over time. The random effects model estimates average effects and treats unobserved heterogeneity as a random variable. In addition, the VIF values are also reported in Table 4, confirming that multicollinearity is not a significant problem.

The System GMM proposed by Blundell & Bond (1998) is employed for the estimation of the dynamic panel, as it accounts for unbalanced panels and addresses the problems of endogeneity and autocorrelation in the error terms. It provides more reliable and unbiased estimates, as the number of cross-sectional units (N) is greater than the number of periods (T) in global data. However, the System GMM suffers from instrument proliferation, which undermines the statistical significance of the Hansen test. To address this issue, specifically in regional sub-samples, the number of instruments is restricted to achieve unbiased results (Roodman, 2009).

Additionally, Panel Quantile Regression and Driscoll-Kraay Standard Errors are also used as robustness checks. Driscoll-Kraay Standard errors also consider cross-sectional dependence.

### *3.4. Descriptive Analysis*

Table 2 provides descriptive statistics.

**Table 2: Descriptive Statistics**

| Variable | Observations | Mean | Std. Dev. | Minimum | Maximum |
|---|---|---|---|---|---|
| **$CO_2$** | 1922 | 3.440 | 4.383 | .021 | 39.582 |
| **GDP** | 1922 | 9216.314 | 15921.25 | 234.709 | 84611.1 |
| **FD** | 1922 | 0.119 | 1.126 | -.772 | 9.509 |
| **IQ** | 1922 | -0.123 | .916 | -1.539 | 2.531 |
| **RE** | 1922 | 40.544 | 32.496 | .01 | 98.27 |
| **TRADE** | 1922 | 81.067 | 48.300 | 9.955 | 437.326 |
| **URB POP** | 1922 | 52.080 | 22.442 | 7.412 | 100 |
| **IND** | 1922 | 28.440 | 12.335 | 4.428 | 86.669 |

### *3.5. Correlation Analysis:*

Table 3 shows the correlation matrix. It shows a positive and significant correlation between all variables and carbon emissions at the global level, except RE consumption, which has a negative relationship with $CO_2$. The correlation between urban population and $CO_2$ is 0.664, which is the highest among all.

**Table 3: Correlation Matrix**

| Variables | $CO_2$ | GDP | FD | IQ | RE | TRADE | URBPOP | IND |
|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | 1.000 | | | | | | | |
| **GDP** | 0.659 | 1.000 | | | | | | |
| **FD** | 0.282 | 0.517 | 1.000 | | | | | |
| **IQ** | 0.475 | 0.798 | 0.522 | 1.000 | | | | |
| **RE** | -0.579 | -0.375 | -0.359 | -0.349 | 1.000 | | | |
| **TRADE** | 0.308 | 0.388 | 0.205 | 0.386 | -0.360 | 1.000 | | |
| **URBPOP** | 0.664 | 0.632 | 0.418 | 0.563 | -0.669 | 0.397 | 1.000 | |
| **IND** | 0.373 | 0.007 | 0.027 | -0.100 | -0.308 | 0.099 | 0.222 | 1.000 |

### *3.6. Cross-Sectional Dependence Test:*

After correlation analysis, Pesaran's (2004) test for cross-sectional independence is applied. A test statistic of 17.09 (p-value $< 0.001$) confirmed the presence of significant cross-sectional dependence across nations, implying the use of more robust techniques, such as Driscoll-Kraay standard errors, to obtain unbiased estimates.

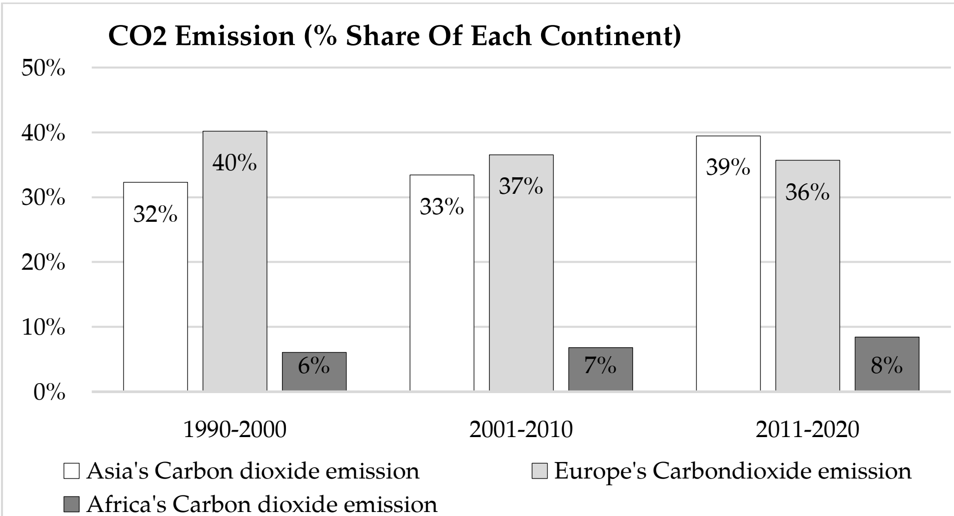
### *3.7. Unit Root Tests*

After cross-sectional dependence, we checked the stationarity of variables by employing the Im-Pesaran and Shin test (IPS-2003) and the Fisher-ADF panel unit root test (1999). These results indicate that the series are stationary in first differences, showing integration of order one, I(1). The details are provided in Appendix B. This signifies the use of suitable econometric techniques, such as system GMM, which ensure robust estimates despite non-stationarity.

## 4. Results and Discussion

Figure 1 illustrates the level of $CO_2$ emissions (percentage) during the last three decades in Asia, Africa, and Europe. $CO_2$ emissions in the continent of Europe have decreased, whereas in Asia and Africa, they have surged.

**Figure 1: CO2 emissions in Asia, Africa and Europe**




The quantitative analysis uses both fixed and random effects models. The fixed effects model permits the use of dummy variables to account for individual-specific effects, with each entity having its own intercept. The regression results from the fixed effects are shown in Table 4, where columns A, B, C, and D display the analysis for the global panel, followed by Asia, Africa, and Europe separately. Economic growth positively influences $CO_2$ emissions both globally and at the continent level, indicating that an increase in GDP is associated with higher $CO_2$ emissions.

The results demonstrate a significant positive effect of FD on $CO_2$ emissions at both the global and continent levels. These findings align with the studies of Bayar *et al*. (2020), Qayyum *et al.* (2021), and Wang *et al.* (2020), which indicate that improved financial access tends to boost production and energy consumption rather than investment in cleaner technologies, resulting in higher carbon emissions in post-transition European economies, India, and N-11 nations. The effectiveness of institutional quality (IQ) in reducing $CO_2$ emissions is presumed, yet an insignificant effect of IQ on $CO_2$ emissions is observed at the global level and in Asia. Conversely, it shows a negative relationship in Africa and a positive one in Europe. This counterintuitive result of IQ in Europe could be due to high industrial activity, accurate emission estimation, or the static nature of the FE model. The sign and magnitude of the interaction term FD*IQ reveal different patterns across regions. It is negative globally and for Asia, indicating a strong dependence between the two variables, and suggesting that effective governance combined with robust financial institutions can significantly reduce $CO_2$ emissions. In contrast, the interaction is insignificant in Africa and positively significant in Europe. The use of renewable energy (RE) contributes to a reduction in $CO_2$ emissions, as evidenced by its negative coefficients across all regions. These results are consistent with the study by Kirikkaleli & Adebayo (2020), which shows similar trends globally, but they contradict the findings of Avazkhodjaev *et al*. (2022), who found that RE generation was associated with increased $CO_2$ emissions in the long run. An increase in urban population also has a significant positive impact on $CO_2$ emissions at both the global and continent levels. Diagnostic test results are provided in Table 4. The VIF scores for multicollinearity range from 2.5 to 4.38, indicating low to moderate multicollinearity. The results for heteroscedasticity and autocorrelation are significant and should be addressed.

**Table 4: Fixed Effects Results**

| | Dependent Variable: Carbon Dioxide Emissions | | | |
|---|---|---|---|---|
| **Variables** | **Global (A)** | **Asia (B)** | **Africa (C)** | **Europe (D)** |
| **LGDP** | 0.389*** | 0.399*** | 0.498*** | 0.107** |
| | (0.0278) | (0.0433) | (0.0484) | (0.0507) |
| **FD** | 0.0959*** | 0.206*** | 0.0468** | 0.0320** |
| | (0.0142) | (0.0206) | (0.0236) | (0.0143) |
| **IQ** | 0.0182 | 0.0116 | -0.100** | 0.110*** |
| | (0.0297) | (0.0379) | (0.0468) | (0.0251) |
| **FD*IQ** | -0.0636*** | -0.123*** | 0.00204 | 0.0305** |
| | (0.00924) | (0.0150) | (0.0123) | (0.0139) |
| **LRE** | -0.316*** | -0.139*** | -0.345*** | -0.300*** |
| | (0.0149) | (0.0219) | (0.0396) | (0.0174) |
| **LTRADE** | 0.0731*** | 0.0228 | 0.162*** | -0.0377 |
| | (0.0197) | (0.0289) | (0.0293) | (0.0432) |
| **LURB POP** | 0.964*** | 0.997*** | 0.615*** | 1.105*** |
| | (0.0631) | (0.113) | (0.0902) | (0.274) |
| **LIND** | 0.128*** | 0.195*** | 0.0216 | 0.484*** |
| | (0.0233) | (0.0384) | (0.0328) | (0.0763) |
| **Constant** | -6.368*** | -6.804*** | -6.133*** | -4.453*** |
| | (0.245) | (0.377) | (0.445) | (1.150) |

| Variables | Global (A) | Asia (B) | Africa (C) | Europe (D) |
|---|---|---|---|---|
| **Dependent Variable: Carbon Dioxide Emissions** | | | | |
| **Observations** | 1,922 | 638 | 875 | 385 |
| **R-squared** | 0.598 | 0.799 | 0.517 | 0.629 |
| **Number of Ids** | 111 | 41 | 47 | 21 |
| **Multicollinearity (VIF)** | 2.58 | 3.64 | 3.34 | 4.38 |
| **Heteroscedasticity** | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **Serial Correlation** | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

**Source:** Authors' calculations; Standard errors in parenthesis $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.1$

Another method used to account for individual-specific effects is the random effects model. It assumes that these effects are uncorrelated with the error term and treats them as random variables. Table 5 displays the results from the random effects model. The findings indicate that greater economic growth leads to increased environmental degradation. A positive and significant effect of FD on $CO_2$ emissions is observed globally and across specific continents. This aligns with the studies of Kirikkaleli & Adebayo (2020) and Batool *et al.* (2022), which reported higher $CO_2$ emissions linked to FD. The highest emissions are in Asia, where a one-unit increase in FD results in a 20.9% rise in $CO_2$ emissions. IQ shows differing effects across regions. It has an insignificant impact on $CO_2$ emissions globally and in Asia but is significantly positive in Europe and negative in Africa. Ibrahim & Law (2016) found similar results for Sub-Saharan African countries, highlighting the importance of institutional reforms. The positive coefficient of IQ in Europe, like that in the FE model, can stem from the same reasons, and the assumption that there is no link between country-specific effects and independent variables in the RE model can contribute to this paradox. The interaction term $FD^*IQ$ indicates that a one-unit change in $FD^*IQ$ causes a 6.8% decrease in $CO_2$ emissions globally and a 12.4% decrease in Asia, though it is insignificant for Africa and positively significant for Europe.

The negative sign of the coefficient on RE supports its role in minimizing $CO_2$ concentration and is more pronounced in Africa (0.331%). The results are consistent with the studies of Sharif *et al.* (2019) and contradict the findings of Adams & Nsiah (2019), who reported a positive relationship between $CO_2$ emissions and RE in the long run. Industrialization and urban population play a significant role in increasing $CO_2$ emissions. The results of the LM and Hausman tests help us choose the most appropriate model, between fixed and random effects, at the global level and for the selected continents.

**Table 5: Random Effects Results**

| Variables | Dependent Variable: Carbon Dioxide Emissions Global (A) | Asia (B) | Africa (C) | Europe (D) |
|---|---|---|---|---|
| **LGDP** | 0.423*** | 0.392*** | 0.593*** | 0.108** |
| | (0.0259) | (0.0402) | (0.0458) | (0.0457) |
| **FD** | 0.0968*** | 0.209*** | 0.0552** | 0.0329** |
| | (0.0140) | (0.0199) | (0.0229) | (0.0140) |
| **IQ** | 6.38e-05 | -0.0147 | -0.0746* | 0.101*** |
| | (0.0284) | (0.0344) | (0.0451) | (0.0247) |
| **FD*IQ** | -0.0680*** | -0.124*** | -0.00396 | 0.0280** |
| | (0.00916) | (0.0145) | (0.0122) | (0.0137) |
| **LRE** | -0.292*** | -0.130*** | -0.331*** | -0.294*** |
| | (0.0132) | (0.0181) | (0.0346) | (0.0166) |
| **LTRADE** | 0.0653*** | 0.0160 | 0.152*** | -0.0339 |
| | (0.0197) | (0.0280) | (0.0294) | (0.0405) |
| **LURB POP** | 0.924*** | 0.990*** | 0.576*** | 0.963*** |
| | (0.0599) | (0.102) | (0.0828) | (0.238) |
| **LIND** | 0.130*** | 0.201*** | 0.0275 | 0.497*** |
| | (0.0235) | (0.0374) | (0.0329) | (0.0740) |
| **Constant** | -6.559*** | -6.714*** | -6.737*** | -3.966*** |
| | (0.236) | (0.361) | (0.416) | (0.964) |
| **Observations** | 1,922 | 638 | 875 | 385 |
| **Number of Ids** | 111 | 41 | 47 | 21 |
| **LM Test** | Random effects model is preferred | Random effects model is preferred | Random effects model is preferred | Random effects model is preferred |
| **Hausman Test** | Random effects model is preferred | Random effects model is preferred | Fixed effects model is preferred | Random effects model is preferred |

Standard errors in parenthesis ***p<0.01, **p<0.05, *p<0.1

To address the issues of endogeneity and unobserved heterogeneity, a more advanced econometric technique, System GMM, is applied, yielding more accurate, consistent, and efficient parameter estimates. The dependent variable, $CO_2$ emissions, is treated as endogenous, while the lagged values of all regressors are used as exogenous instrumental variables. The estimated coefficients are presented in Table 6. The significant coefficients support the existence of a nonlinear relationship among the variables. The significant coefficient on the lagged variable $CO_{2(t-1)}$ indicates that current $CO_2$ emissions depend on emissions from the previous year, implying that a one-unit increase in $CO_2$ emissions globally results in a 79.6% increase in emissions this year. The increases in

$CO_2$ emissions for Asia, Africa, and Europe are 57.9%, 59.6%, and 68.5%, respectively.

A significant positive relationship between GDP and $CO_2$ emissions indicates environmental deterioration caused by increased economic growth, suggesting the need for green growth policies. FD has a significant positive relationship with $CO_2$ emissions globally and in Asia and Africa, but a one-unit increase in FD decreases $CO_2$ emissions by 0.0503 percent in Europe. This result is contrary to the studies of Gok (2020) and Bayar *et al.* (2020), who found a positive relationship between $CO_2$ emissions and FD in Europe. Gok (2020) attributed this difference in results to the design and characteristics of the studies, such as the region, time period, estimation technique, and indicators used for FD.

The direct effect of IQ on $CO_2$ emissions is negative across the globe and in specific continents, indicating that effective governance can abate $CO_2$ emissions. The significant coefficients of the interaction term FD*IQ also confirm the nonlinearity of the relationship. The parameters of the estimated variables show a significant negative relationship with $CO_2$ emissions globally and by continent. A one-unit increase in FD, moderated by IQ, is estimated to decrease $CO_2$ emissions by 5.9%, 4.7%, 2.02%, and 3.61% at the global and regional levels in Asia, Africa, and Europe. The results support the existence of the Porter Hypothesis, which relates to the application of environmental standards and advocates the use of high-quality institutions to facilitate green investments. Our results also align with the findings of Hunjra *et al.* (2020).

Consumption of RE helps mitigate $CO_2$ emissions and is highest in Europe (9.34%), necessitating the integration of more renewable resources into existing energy systems. The possible reasons are the technological innovations that increase fuel efficiency, reliance on electric vehicles for transportation, green financing, and heavy reliance on RE sources for power generation. This negative relationship between RE and $CO_2$ supports the findings of Shaari *et al*. (2020) and Mukhtarov *et al*. (2023), and contradicts the findings of Apergis & Payne (2010), who found a positive relationship between $CO_2$ emissions and RE. Trade has a positive effect on global $CO_2$ emissions, whereas it is insignificant in Asia, Africa, and Europe.

Industrialization and urban population degrade environmental quality globally, including across continents, except in Europe, where a higher urban population share is negatively related to $CO_2$ emissions. This highlights the importance of sustainable urban planning, effective management, and strict environmental regulation enforcement. This finding is also supported by the study conducted by Khoshnevis Yazdi & Shakouri (2018), which found a negative impact of increased urbanization on $CO_2$ emissions in Europe, while studies by Ponce de Leon Barido & Marshall (2014) show an elastic relationship between rising urbanization and $CO_2$ emissions.

The results of Arellano Bond AR(1) and AR(2) indicate the absence of both first and second order autocorrelation. Also, the Hansen J-test values lie within the acceptable range, ensuring the validity of instruments.

**Table 6: System GMM Results**

| | **Dependent Variable: Carbon Dioxide Emissions** | | | |
|---|---|---|---|---|
| **Variables** | **Global (A)** | **Asia (B)** | **Africa (C)** | **Europe (D)** |
| **$CO_{2i,t-1}$** | $0.796^{***}$ | $0.579^{***}$ | $0.596^{***}$ | $0.685^{***}$ |
| | (0.00645) | (0.0912) | (0.0650) | (0.0985) |
| **LGDP** | $0.161^{***}$ | $0.148^{***}$ | $0.364^{***}$ | $0.143^{***}$ |
| | (0.00669) | (0.0343) | (0.0645) | (0.0362) |
| **FD** | $0.0255^{***}$ | $0.110^{***}$ | $0.0849^{***}$ | $-0.0503^{***}$ |
| | (0.00441) | (0.0221) | (0.0159) | (0.0140) |
| **IQ** | $-0.0719^{***}$ | $-0.0527^{***}$ | $-0.0445^{**}$ | $-0.0851^{***}$ |
| | (0.00532) | (0.0153) | (0.0213) | (0.0220) |
| **FD*IQ** | $-0.0595^{***}$ | $-0.0479^{***}$ | $-0.0202^{***}$ | $-0.0361^{***}$ |
| | (0.00295) | (0.0109) | (0.00704) | (0.0127) |
| **LRE** | $-0.0288^{***}$ | $-0.0484^{***}$ | $-0.0672^{***}$ | $-0.0934^{***}$ |
| | (0.00318) | (0.0130) | (0.00842) | (0.0302) |
| **LTRADE** | $0.0303^{***}$ | 0.0114 | 0.0281 | -0.0573 |
| | (0.00658) | (0.00878) | (0.0242) | (0.0353) |
| **LURB POP** | $0.0552^{***}$ | $0.353^{***}$ | $0.137^{***}$ | $-0.354^{*}$ |
| | (0.00589) | (0.124) | (0.0320) | (0.202) |
| **LIND** | $0.0511^{***}$ | $0.187^{***}$ | $0.0953^{***}$ | 0.0132 |
| | (0.00769) | (0.0298) | (0.0271) | (0.108) |
| **Constant** | $-1.608^{***}$ | $-2.778^{***}$ | $-3.586^{***}$ | -0.874 |
| | (0.0790) | (0.713) | (0.629) | (0.991) |
| **Observations** | 1,920 | 635 | 875 | 385 |
| **Number of Ids** | 111 | 41 | 47 | 21 |
| **AR (1) Pr>z** | 0.373 | 0.410 | 0.057 | 0.160 |
| **AR (2) Pr>z** | 0.592 | 0.558 | 0.146 | 0.530 |
| **Hansen Test** | 0.734 | 0.942 | 0.807 | 0.877 |

Standard errors in parenthesis $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.1$

## 5. Robustness check

### *5.1. Panel Quantile Regression Results*

To assess the robustness of the findings, panel quantile regression analysis is conducted, and the results are presented in Table 7.

**Table 7: Panel Quantile Regression Results**

| Variables | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 |
|---|---|---|---|---|---|---|---|---|---|
| LGDP | 1.032*** | 0.980*** | 0.948*** | 0.920*** | 0.898*** | 0.866*** | 0.819*** | 0.756*** | 0.669*** |
| | (0.025) | (0.021) | (0.020) | (0.020) | (0.021) | (0.023) | (0.027) | (0.033) | (0.043) |
| FD | 0.101*** | 0.111*** | 0.117*** | 0.122*** | 0.126*** | 0.132*** | 0.140*** | 0.152*** | 0.168*** |
| | (0.017) | (0.015) | (0.015) | (0.014) | (0.015) | (0.016) | (0.018) | (0.023) | (0.030) |
| IQ | -0.130*** | -0.135*** | -0.138*** | -0.140*** | -0.142*** | -0.145*** | -0.149*** | -0.155*** | -0.163*** |
| | (0.024) | (0.021) | (0.020) | (0.020) | (0.021) | (0.022) | (0.026) | (0.032) | (0.042) |
| FD*IQ | -0.400*** | -0.367*** | -0.348*** | -0.331*** | -0.318*** | -0.298*** | -0.269*** | -0.231*** | -0.177*** |
| | (0.019) | (0.016) | (0.016) | (0.016) | (0.016) | (0.018) | (0.021) | (0.026) | (0.033) |
| LRE | -0.060*** | -0.079*** | -0.091*** | -0.101*** | -0.108*** | -0.120*** | -0.137*** | -0.160*** | -0.191*** |
| | (0.011) | (0.010) | (0.009) | (0.009) | (0.010) | (0.011) | (0.013) | (0.015) | (0.020) |
| LTRADE | .0432 | 0.065** | 0.079*** | 0.090*** | 0.099*** | 0.113*** | 0.132*** | 0.158*** | 0.195*** |
| | (0.030) | (0.026) | (0.025) | (0.025) | (0.026) | (0.028) | (0.032) | (0.040) | (0.052) |
| LURB POP | 0.412*** | 0.466*** | 0.499*** | 0.528*** | 0.550*** | 0.583*** | 0.631*** | 0.696*** | 0.786*** |
| | (0.045) | (0.039) | (0.038) | (0.038) | (0.039) | (0.042) | (0.048) | (0.060) | (0.079) |
| LIND | 0.238*** | 0.255*** | 0.265*** | 0.274*** | 0.281*** | 0.290*** | 0.305*** | 0.325*** | 0.353*** |
| | (0.037) | (0.032) | (0.031) | (0.032) | (0.032) | (0.034) | (0.040) | (0.049) | (0.065) |

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The results support a decline in $CO_2$ emissions across all quantiles. The negative impact of the interaction term (FD*IQ), IQ, and RE remains the same across all quantiles and is consistent with the previous findings. These results suggest that at higher levels of $CO_2$ emissions, IQ and RE contribute to improved environmental quality, whereas the impact of FD*IQ decreases because of a change in the coefficient's magnitude. The coefficient of GDP shows the magnitude of the relationship between GDP (FD, trade, urban population, and industrialization) and $CO_2$ across the distribution of $CO_2$ emissions, which is positive and statistically significant across all quantiles suggesting that increase in GDP (FD, trade, urban population and industrialization) will increase $CO_2$ emissions across all quantiles, consistent with our previous findings.

### *5.2 Driscoll-Kray Standard Errors*

The study used Driscoll and Kray's standard errors to account for cross-sectional dependence and to examine the robustness of the results. The impact of RE remains the same across all panels, while the effect of

FD*IQ becomes insignificant in Europe. This result indeed suggests regional heterogeneity in the mediating role of institutional quality. The possible reasons are as follows: First, European economies generally exhibit higher institutional quality (IQ) and financial development (FD) than other regions. The marginal benefit of further improvements in FD*IQ on $CO_2$ reduction may diminish at higher levels of economic development. At a higher level of development, the public prioritizes environmental quality as suggested by the EKC. Second, Europe's stringent climate policies may dominate the FD-IQ mediation pathway, making their interaction effect statistically insignificant in our model. Third, Europe's highly complex and saturated financial systems may require more nuanced measures of FD and IQ than our model captures, potentially obscuring their interaction effects. Thus, in the case of Europe, it suggests that environmental regulation becomes embedded in state apparatus and corporate norms, reducing dependency on financial-institutional mediation. Moreover, green innovation becomes systemic rather than market-dependent.

**Table 8: Driscoll-Kray Standard Errors**

| | Dependent Variable: Carbon Dioxide Emissions | | | |
|---|---|---|---|---|
| **Variables** | **Global (A)** | **Asia (B)** | **Africa (C)** | **Europe (D)** |
| **LGDP** | 0.8731*** | 0.3445*** | 0.9913*** | 0.2697*** |
| | (0.0369) | (0.0823) | (0.0207) | (0.0867) |
| **FD** | 0.1305*** | 0.2249*** | 0.2585*** | 0.0078 |
| | (0.0080) | (0.0301) | (0.0207) | (0.0445) |
| **IQ** | -0.1445*** | -0.0562 | 0.0218 | -0.1672*** |
| | (0.0248) | (0.0387) | (0.0148) | (0.0391) |
| **FD*IQ** | -0.3022*** | -0.1208*** | -0.0955*** | 0.0073 |
| | (0.0300) | (0.0101) | (0.0137) | (0.0375) |
| **LRE** | -0.1178*** | -0.1114*** | -0.1167*** | -0.2357*** |
| | (0.0085) | (0.0076) | (0.0169) | (0.0234) |
| **LTRADE** | 0.1098*** | -0.0062 | -0.001 | 0.1455* |
| | (0.0225) | (0.0203) | (0.0366) | (0.0708) |
| **LURB POP** | 0.5762*** | 1.0645*** | 0.4261*** | 0.5259* |
| | (0.0712) | (0.1359) | (0.0718) | (0.2777) |
| **LIND** | 0.2887*** | 0.4722*** | 0.2686*** | 0.7098*** |
| | (0.0526) | (0.0440) | (0.0471) | (0.1053) |
| **Constant** | -9.9513*** | -7.4846*** | -9.9569*** | -5.353*** |
| | (0.1879) | (0.1864) | (0.2914) | (0.4345) |
| **Observations** | 1,922 | 638 | 875 | 385 |
| **Number of Ids** | 111 | 41 | 47 | 21 |
| **R-Squared** | 0.896 | 0.918 | 0.918 | 0.597 |

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

## 6. Conclusion and Policy Recommendations

The exploration of the relationship between FD and IQ has become a key focus for researchers worldwide. Efforts to combat climate change and promote green growth help achieve several Sustainable Development Goals (SDGs), particularly SDG 13 related to climate action. Growing environmental concerns and the need for a cleaner, safer environment have led to investigations into how FD and IQ relate to environmental degradation ($CO_2$ emissions) at both the global and continent levels (Asia, Africa, and Europe).

The study takes an interesting turn when the mediating role of IQ comes into play. The interaction term $FD^*IQ$ is important in resolving whether financial institutions, along with effective governance, help curb or increase $CO_2$ emissions. This key role of FD aligns with SDG 9, which focuses on promoting technological innovation and sustainable industrialization. Additionally, the analysis is not limited to a specific region; it covers the global level and extends to the continents of Asia, Africa, and Europe to show how differences in institutional structures can impact $CO_2$ emissions across the world. The study conducts an empirical analysis of the global panel and the continents of Asia, Africa, and Europe, covering the years from 1990 to 2020.

The association between the variables is examined using traditional econometric techniques, including fixed- and random-effect models. A two-step system GMM is then used to obtain efficient and consistent estimates in the presence of endogeneity. The results show that economic growth increases $CO_2$ emissions worldwide. This goes against SDG 8, which emphasizes promoting sustainable economic growth. FD increases $CO_2$ emissions globally and across Asia and Africa, while well-developed financial institutions in Europe lead to a decline in $CO_2$ emissions. The quality of institutions and its moderating effect, $FD^*IQ$, yield a significant negative relationship across the globe and in the specific continents, rejecting the null hypothesis of no significant moderating effect of $FD^*IQ$. This demonstrates that strong institutions, along with well-developed and well-managed financial institutions, help reduce carbon emissions by transitioning from non-renewable to renewable energy sources and stimulating green growth. The robustness check using Panel quantile and Driscoll and Kraay standard error approaches also supports our findings.

Institutions that manage risk, enforce agreements, and ensure fair distribution of gains build investor confidence in long-term, environmentally friendly projects. This supports SDG 16: Peace, Justice, and Strong Institutions, which promotes resilient and sustainable development. The use and deployment of renewable energy (RE) across various sectors reduces atmospheric $CO_2$ levels worldwide, aiding SDG 7: Affordable and Clean Energy. Although trade significantly affects $CO_2$ emissions globally, its effects is statistically insignificant in Asia, Africa, and Europe. Urban growth and industrialization increase $CO_2$ emissions, except in Europe, where industrialization has little effect, and a higher population correlates with a decrease in emissions.

Based on the findings of this study and the diverse economic, institutional, and ecological settings across Asia, Africa, and Europe, a region-specific policy is essential. In Asia, policymakers should strengthen institutional quality by ensuring transparency, equity, and accountability while incentivizing financial institutions to spur investment in RE, smart grids, and green hydrogen. The African nations should prioritize the adoption and expansion of decentralized RE systems, such as solar microgrids, battery storage systems, and biomass generators, to meet increasing energy demand, and establish strong, capable regulatory authorities to monitor these systems and attract climate finance for the region. The European nations should expand the use of innovative financial instruments such as green bonds and securities, with strict monitoring policies to affirm their commitment to a low-carbon economy. This context-specific approach will ensure that each region can successfully make a move towards a sustainable economy.

The study has certain limitations: missing data reduced the sample size, potential omitted variable bias exists despite using system GMM, and the data quality varies, especially across countries with weak institutional structures. The panel data at the global and regional levels may have overlooked country-specific dynamics that could significantly influence results. The primary focus of this research was on panel data rather than time series analysis, leaving room for future exploration of stationarity within sub-samples. Additionally, for the continent-level analysis, only three continents—Asia, Africa, and Europe—were included; therefore, future studies could include Australia, North America, and South America to account for geographical and institutional differences for a more comprehensive understanding.

Future studies can extend this research in many ways: employing advanced causal inference methods to investigate the causal relationships between FD, RE, and IQ, incorporating technological innovations like smart grids, carbon capture and storage (CCS), hydrogen economy, and blockchain technology into the analysis can provide an in-depth understanding of the efficacy of these innovations and their consequent effect on $CO_2$ emissions. To get a comprehensive view of the impact of these variables on $CO_2$ emissions, including the externalities associated with RE adoption, such as employment levels, can also be considered. Advanced econometric techniques, such as polynomial regression and machine learning algorithms, can be used to explore the non-linear relationship between the variables. A comparative analysis comprising the countries having differences in economic development, institutional structures, and cultural factors can shed light on how significant these factors are in improving environmental quality and combating climate change.

## References

Adams, S., & Nsiah, C. (2019). Reducing carbon dioxide emissions; Does renewable energy matter? *Science of the Total Environment*, *693*, 133288(1-9).

Adedoyin, F. F., Bekun, F. V., Eluwole, K. K., & Adams, S. (2022). Modelling the nexus between financial development, FDI, and $CO_2$ emission: Does institutional quality matter? *Energies*, *15*(20), 7464(1-17).

Ahmad, M., Khattak, S. I., Khan, A., & Rahman, Z. U. (2020). Innovation, foreign direct investment (FDI), and the energy–pollution–growth nexus in OECD region: A simultaneous equation modeling approach. *Environmental and Ecological Statistics*, *27*, 203-232.

Alpan, K., Tuncal, K., Ozkan, C., Sekeroglu, B., & Ever, Y. K. (2022). Design and simulation of global model for carbon emission reduction using IoT and artificial intelligence. *Procedia Computer Science*, *204*, 627-634.

Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy*, *38*(1), 656-660.

Aufderheide, P., & Rich, B. (1988). Environmental reform and the multilateral banks. *World Policy Journal*, *5*(2), 301-321.

Avazkhodjaev, S., Usmonov, J., Bohdalová, M., & Lau, W. Y. (2022). The causal nexus between renewable energy, $CO_2$ emissions, and economic growth: New evidence from CIS countries. *International Journal of Energy Economics and Policy*, *12*(6), 248-260.

Awais, M., Afzal, A., Firdousi, S., & Hasnaoui, A. (2023). Is fintech the new path to sustainable resource utilisation and economic development? *Resources Policy*, *81*, 103309(1-11).

Azam, M., Khan, A. Q., & Ozturk, I. (2019). The effects of energy on investment, human health, environment and economic growth: Empirical evidence from China. *Environmental Science and Pollution Research*, *26*, 10816-10825.

Azam, M., Rehman, Z. U., & Ibrahim, Y. (2022). Causal nexus in industrialization, urbanization, trade openness, and carbon emissions: Empirical evidence from OPEC economies. *Environment, Development and Sustainability*, 1-21.

Baloch, M. A., Zhang, J., Iqbal, K., & Iqbal, Z. (2019). The effect of financial development on ecological footprint in BRI countries: Evidence from panel data estimation. *Environmental Science and Pollution Research*, *26*, 6199-6208.

Bansal, S. (2014). Environmental quality: impact of economic growth. *Environment and Development Economics*, *20*(5), 673-696.

Batool, Z., Raza, S. M. F., Ali, S., & Abidin, S. Z. U. (2022). ICT, renewable energy, financial development, and $CO_2$ emissions in developing countries of East and South Asia. *Environmental Science and Pollution Research*, *29*(23), 35025-35035.

Bayar, Y., Diaconu, L., & Maxim, A. (2020). Financial development and $CO_2$ emissions in post-transition European Union countries. *Sustainability*, *12*(7), 2640(1-15).

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, *87*(1), 115-143.

Brem, A., Maier, M., & Wimschneider, C. (2016). Competitive advantage through innovation: The case of Nespresso. *European Journal of Innovation Management*, *19*(1), 133-148.

Calderon, C., & Liu, L. (2003). The direction of causality between financial development and economic growth. *Journal of Development Economics*, *72*(1), 321-334.

Charfeddine, L. (2017). The impact of energy consumption and economic development on ecological footprint and $CO_2$ emissions: Evidence from a Markov switching equilibrium correction model. *Energy Economics*, *65*, 355-374.

Chen, J., Su, F., Jain, V., Salman, A., Tabash, M. I., Haddad, A. M., ... & Shabbir, M. S. (2022). Does renewable energy matter to achieve sustainable development goals? The impact of renewable energy strategies on sustainable economic growth. *Frontiers in Energy Research*, *10*, 829252(1-7).

Cheng, S. Y., Yu, C. P., & Hou, H. (2025). Investigating the role of financial development in mitigating carbon emissions across diverse financial economies. *Economic Change and Restructuring*, *58*(1), 11(1-31).

Chirwa, M. (2023). The dynamics of Man's history and economic development: A refocus on ecological disturbance and climate change. *Civil Engineering and Urban Planning: An International Journal, 10*(1), 1-23.

Chong, S. H., Tun, Y. L., Shah, S. Z., & Rasiah, R. (2022). Environmental quality and economic growth: An empirical analysis in Asian countries. *Environment-Behaviour Proceedings Journal*, *7*(21), 367-372.

Croutzet, A., & Dabbous, A. (2021). Do FinTech trigger renewable energy use? Evidence from OECD countries. *Renewable Energy*, *179*, 1608-1617.

Danish, & Ulucak, R. (2020). The pathway toward pollution mitigation: Does institutional quality make a difference? *Business Strategy and the Environment*, *29*(8), 3571-3583.

Darcin, M. (2014). Association between air quality and quality of life. *Environmental Science and Pollution Research*, *21*(3), 1954-1959.

Dietz, T., & Rosa, E. A. (1997). Effects of population and affluence on $CO_2$ emissions. *Proceedings of the National Academy of Sciences*, *94*(1), 175-179.

Dinca, G., Barbuța, M., Negri, C., Dinca, D., & Model, L. S. (2022). The impact of governance quality and educational level on environmental performance. *Frontiers in Environmental Science*, *10*, 950683(1-15).

Dong, F., Wang, Y., Su, B., Hua, Y., & Zhang, Y. (2019). The process of peak $CO_2$ emissions in developed economies: A perspective of industrialization and urbanization. *Resources, Conservation and Recycling*, *141*, 61-75.

Ehrlich, P. R., & Holdren, J. P. (1971). Impact of Population Growth: Complacency concerning this component of man's predicament is unjustified and counterproductive. *Science*, *171*(3977), 1212-1217.

Gok, A. (2020). The role of financial development on carbon emissions: A meta regression analysis. *Environmental Science and Pollution Research*, *27*(11), 11618-11636.

Godil, D. I., Sharif, A., Agha, H., & Jermsittiparsert, K. (2020). The dynamic nonlinear influence of ICT, financial development, and institutional quality on $CO_2$ emission in Pakistan: New insights from QARDL approach. *Environmental Science and Pollution Research*, *27*, 24190-24200.

Ha, D., & Nguyen, Y. (2023). Institutional quality's influence on financial inclusion'impact on bank stability. *Cogent Economics & Finance*, *11*(1), 2190212(1-22).

Habiba, U., & Xinbang, C. (2022). The impact of financial development on $CO_2$ emissions: New evidence from developed and emerging countries. *Environmental Science and Pollution Research*, *29*(21), 31453-31466.

Hafeez, M., Chunhui, Y., Strohmaier, D., Ahmed, M., & Jie, L. (2018). Does finance affect environmental degradation: Evidence from One Belt and One Road Initiative region? *Environmental Science and Pollution Research*, *25*, 9579-9592.

Haldar, A., & Sethi, N. (2021). Effect of institutional quality and renewable energy consumption on $CO_2$ emissions: An empirical investigation for developing countries. *Environmental Science and Pollution Research*, *28*(12), 15485-15503.

Hassaballa, H. (2015). The effect of corruption on carbon dioxide emissions in the MENA region. *European Journal of Sustainable Development*, *4*(2), 301-301.

Hunjra, A. I., Tayachi, T., Chani, M. I., Verhoeven, P., & Mehmood, A. (2020). The moderating effect of institutional quality on the financial development and environmental quality nexus. *Sustainability*, *12*(9), 3805(1-13).

Ibrahim, M. H., & Law, S. H. (2016). Institutional quality and $CO_2$ emission–trade relations: Evidence from Sub-Saharan Africa. *South African Journal of Economics*, *84*(2), 323-340.

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of econometrics*, *115*(1), 53-74.

Islam, M. S. (2022). Does financial development cause environmental pollution? Empirical evidence from South Asia. *Environmental Science and Pollution Research*, *29*(3), 4350-4362.

Jensen, V., 1996. The pollution haven hypothesis and the industrial flight hypothesis: some perspectives on theory and empirics. Working Paper 1996.5, Centre for Development and the Environment, University of Oslo.

Jiang, C., & Ma, X. (2019). The impact of financial development on carbon emissions: A global perspective. *Sustainability*, *11*(19), 5241(1-22).

Khan, H., Weili, L., Khan, I., & Zhang, J. (2023). The nexus between natural resources, renewable energy consumption, economic growth, and carbon dioxide emission in BRI countries. *Environmental Science and Pollution Research*, *30*(13), 36692-36709.

Khan, I., Zakari, A., Ahmad, M., Irfan, M., & Hou, F. (2022). Linking energy transitions, energy consumption, and environmental sustainability in OECD countries. *Gondwana Research*, *103*, 445-457.

Khan, M., & Rana, A. T. (2021). Institutional quality and $CO_2$ emission–output relations: The case of Asian countries. *Journal of Environmental Management*, *279*, 111569(1-16).

Khan, M. I., Teng, J. Z., & Khan, M. K. (2020). The impact of macroeconomic and financial development on carbon dioxide emissions in Pakistan: Evidence with a novel dynamic simulated ARDL approach. *Environmental Science and Pollution Research*, *27*, 39560-39571.

Khoshnevis Yazdi, S., & Shakouri, B. (2018). The effect of renewable energy and urbanization on CO2 emissions: A panel data. *Energy Sources, Part B: Economics, Planning, and Policy*, *13*(2), 121-127.

Kirikkaleli, D., & Adebayo, T. S. (2020). Do renewable energy consumption and financial development matter for environmental sustainability? New global evidence. *Sustainable Development*, *29*(4), 583-594.

Le, T. H., Chang, Y., & Park, D. (2016). Trade openness and environmental quality: International evidence. *Energy Policy*, *92*, 45-55.

Li, X., Ozturk, I., Majeed, M. T., Hafeez, M., & Ullah, S. (2022). Considering the asymmetric effect of financial deepening on environmental quality in BRICS economies: Policy options for the green economy. *Journal of Cleaner Production, 331,* 129909(1-9).

Li, X., Jiang, M., Lin, C., Chen, R., Weng, M., & Jim, C. Y. (2025). Integrated BIM-IoT platform for carbon emission assessment and tracking in prefabricated building materialization. *Resources, Conservation and Recycling*, *215*, 108122(1-15).

Liobikiene, G., & Butkus, M. (2019). Scale, composition, and technique effects through which the economic growth, foreign direct investment, urbanization, and trade affect greenhouse gas emissions. *Renewable energy*, *132*, 1310-1322.

Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and statistics*, *61*(S1), 631-652.

Magazzino, C., Toma, P., Fusco, G., Valente, D., & Petrosillo, I. (2022). Renewable energy consumption, environmental degradation and economic growth: The greener the richer? *Ecological Indicators*, *139*, 108912(1-12).

Majeed, M. T., & Luni, T. (2020). Renewable energy, circular economy indicators and environmental quality: A global evidence of 131 countries with heterogeneous income groups. *Pakistan Journal of Commerce and Social Sciences*, *14*(4), 866-912.

Majeed, M. T., & Tauqir, A. (2020). Effects of urbanization, industrialization, economic growth, energy consumption, financial development on carbon emissions: An extended STIRPAT model for heterogeneous income groups. *Pakistan Journal of Commerce and Social Sciences*, *14*(3), 652-681.

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens III, W. W. (1972). The Limits to Growth, Universe, New York. *Earth Island, London*.

Mrabet, Z., Alsamara, M., Mimouni, K., Mnasri, A. (2021). Can human development and political stability improve environmental quality? New evidence from the MENA region. *Economic Modelling 94*, 28–44.

Muhoza, B. K. (2019). Financial intermediation and economic growth in the East African Community: A financial index approach. *African Journal of Economic Review*, *7*(2), 165-182.

Mukhtarov, S., Aliyev, F., Aliyev, J., & Ajayi, R. (2023). Renewable energy consumption and carbon emissions: Evidence from an oil-rich economy. *Sustainability*, *15*(1), 134(1-12).

Pagano, M. (1993). Financial markets and growth: An overview. *European Economic Review*, *37*(2-3), 613-622.

Panayotou, T. (1997). Demystifying the environmental1-15) Kuznets curve: Turning a black box into a policy tool. *Environment and Development Economics*, *2*(4), 465-484.

Pata, U. K. (2018). The effect of urbanization and industrialization on carbon emissions in Turkey: Evidence from ARDL bounds testing procedure. *Environmental Science and Pollution Research*, *25*(8), 7740-7747.

Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels. Cambridge Working Papers. *Economics*, *1240*(1-46).

Ponce de Leon Barido, D., & Marshall, J. D. (2014). Relationship between urbanization and $CO_2$ emissions depends on income level and policy. *Environmental science & technology*, *48*(7), 3632-3639.

Porter, M. (1991). "America's Green Strategy." Scientific American, 264(4), 168.

Qayyum, M., Ali, M., Nizamani, M. M., Li, S., Yu, Y., & Jahanger, A. (2021). Nexus between financial development, renewable energy consumption, technological innovations and $CO_2$ emissions: The case of India. *Energies*, *14*(15), 4505(1-19).

Ritchie, H., Roser, M., & Rosado, P. (2024, January). $CO_2$ and Greenhouse Gas Emissions. Our World in Data. Retrieved from https://ourworldindata.org/co2-and-greenhouse-gas-emissions

Roodman, D. (2009). A note on the theme of too many instruments. *Oxford Bulletin of Economics and statistics*, *71*(1), 135-158.

Ruan, S., Wan, G., Le, X., Zhang, S., & Yu, C. (2023). Combining the role of the banking sector and natural resource utilization on green economic development: Evidence from China. *Resources Policy*, *83*, 103671(1-8).

Sakilu, O. B., & Chen, H. (2024). Realizing Carbon Neutrality in Top-Emitter Countries: Do Green Technology Innovation, Renewable Energy, Financial Development, and Environmental Tax Matters? *Sustainability*, *17*(1), 37(1-26)

Salman, M., Long, X., Dauda, L., & Mensah, C. N. (2019). The impact of institutional quality on economic growth and carbon emissions: Evidence from Indonesia, South Korea and Thailand. *Journal of Cleaner Production*, *241*, 118331(1-15).

Schmidheiny, S., & Zorraquin, F. J. (1998). *Financing change: The financial community, eco-efficiency, and sustainable development*. MIT press.

Shaari, M. S., Abidin, N. Z., & Karim, Z. A. (2020). The impact of renewable energy consumption and economic growth on $CO_2$ emissions: New evidence using Panel ARDL study of selected countries. *International Journal of Energy Economics and Policy*, *10*(6), 617-623.

Sharif, A., Raza, S. A., Ozturk, I., & Afshan, S. (2019). The dynamic relationship of renewable and nonrenewable energy consumption with $CO_2$ emission: A global study with the application of heterogeneous panel estimations. *Renewable Energy*, *133*, 685-691.

Sheraz, M., Deyi, X., Sinha, A., Mumtaz, M. Z., & Fatima, N. (2022). The dynamic nexus among financial development, renewable energy and carbon emissions: Moderating roles of globalization and institutional quality across BRI countries. *Journal of Cleaner Production*, *343*, 130995(1-12).

Shoaib, H. M., Rafique, M. Z., Nadeem, A. M., & Huang, S. (2020). Impact of financial development on CO 2 emissions: a comparative analysis of developing countries (D 8) and developed countries (G8). *Environmental Science and Pollution Research*, *27*, 12461-12475.

Sineviciene, L., Kubatko, O., Derykolenko, O., & Kubatko, O. (2018). The impact of economic performance on environmental quality in developing countries. *International Journal of Environmental Technology and Management*, *21*(5-6), 222-237.

Solaymani, S., & Montes, O. (2024). The role of financial development and good governance in economic growth and environmental sustainability. *Energy Nexus*, *13*, 100268 (1-10).

Sun, X., Chenggang, Y., Khan, A., Hussain, J., & Bano, S. (2021). The role of tourism, and natural resources in the energy-pollution-growth nexus: An analysis of belt and road initiative countries. *Journal of Environmental Planning and Management*, *64*(6), 999-1020.

Sun, Z., Zhang, X., & Gao, Y. (2023). The Impact of financial development on renewable energy consumption: A multidimensional analysis based on global panel data. *International Journal of Environmental Research and Public Health*, *20*(4), 3124(1-20).

Tahir, T., Luni, T., Majeed, M. T., & Zafar, A. (2021). The impact of financial development and globalization on environmental quality: Evidence from South Asian economies. *Environmental Science and Pollution Research, 28*(7), 8088-8101.

Tamazian, A., & Rao, B. B. (2010). Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. *Energy Economics*, *32*(1), 137-145.

Tsokov, T., & Petrova-Antonova, D. (2017, July). EcoLogic: IoT Platform for Control of Carbon Emissions. In *ICSOFT* (pp. 178-185).

Trevisan, R., Ghiani, E., & Pilo, F. (2023). Renewable Energy Communities in Positive Energy Districts: A Governance and Realisation Framework in Compliance with the Italian Regulation. *Smart Cities*, *6*(1), 563-585.

Udeagha, M. C., & Breitenbach, M. C. (2023). The role of financial development in climate change mitigation: Fresh policy insights from South Africa. *Biophysical Economics and Sustainability*, *8*(1), 1-34.

United Nations. (2015). Transforming our world: The 2030 agenda for sustainable development. *New York: United Nations, Department of Economic and Social Affairs*.

United Nations. (n.d.). *Renewable energy: Powering a safer future*. United Nations. Retrieved [September 18, 2024], from https://www.un.org/en/climatechange/raising-ambition/renewable-energy

Usman, O., Alola, A. A., & Sarkodie, S. A. (2020). Assessment of the role of renewable energy consumption and trade policy on environmental degradation using innovation accounting: Evidence from the US. *Renewable Energy*, *150*, 266-277.

Vatamanu, A. F., & Zugravu, B. G. (2023). Financial development, institutional quality and renewable energy consumption. A panel data approach. *Economic Analysis and Policy*, *78*, 765-775.

Wang, R., Mirza, N., Vasbieva, D. G., Abbas, Q., & Xiong, D. (2020). The nexus of carbon emissions, financial development, renewable energy consumption, and technological innovation: What should be the priorities in light of COP 21 Agreements? *Journal of Environmental Management*, *271*, 111027(1-7).

Wang, C. A., Wang, L., Zhao, S., Yang, C., & Albitar, K. (2024). The impact of Fintech on corporate carbon emissions: Towards green and sustainable development. *Business Strategy and the Environment*, *33*(6), 5776-5796.

Wawrzyniak, D., & Dory□, W. (2020). Does the quality of institutions modify the economic growth-carbon dioxide emissions nexus? Evidence from a group of emerging and developing countries. *Economic Research-Ekonomska Istraž ivanja*, *33*(1), 124-144.

World Bank (2023). World development indicators. World Bank: Washington DC.

Xu, J., Chen, F., Zhang, W., Liu, Y., & Li, T. (2023). Analysis of the carbon emission reduction effect of Fintech and the transmission channel of green finance. *Finance Research Letters*, *56*, 104127(1-8).

Xaisongkham, S., & Liu, X. (2024). Institutional quality, employment, FDI and environmental degradation in developing countries: Evidence from the balanced panel GMM estimator. *International Journal of Emerging Markets*, *19*(7), 1920(1-20).

Zhang, J., Ahmad, M., Muhammad, T., Syed, F., Hong, X., & Khan, M. (2023). The impact of the financial industry and globalization on environmental quality. *Sustainability*, *15*(2), 1705(1-18).

Zheng, S., Ahmed, D., Xie, Y., Majeed, M. T., & Hafeez, M. (2023). Green growth and carbon neutrality targets in China: do financial integration and ICT matter? *Journal of Cleaner Production, 405,* 136923(1-10)

## Appendix A

### Table A1: Results of PCA for FD

| Initial Eigenvalues | | | |
|---|---|---|---|
| **Component** | **Eigenvalue** | **Proportion** | **Cumulative** |
| Comp 1 | 2.811 | 0.937 | 0.937 |
| Comp 2 | 0.175 | 0.058 | 0.995 |
| Comp 3 | 0.012 | 0.004 | 1.000 |
| **PCA Rotation** | | | |
| **Component** | **Variance** | **Proportion** | **Cumulative** |
| Comp 1 | 1.000 | 0.333 | 0.333 |
| Comp 2 | 0.999 | 0.333 | 0.666 |
| Comp 3 | 0.999 | 0.333 | 1.000 |
| **PC (Eigenvectors)** | | | |
| **Variable** | **Comp 1** | **Comp 2** | **Comp 3** |
| bm | 0.559 | 0.829 | 0.008 |
| dcp | 0.586 | -0.388 | -0.710 |
| dcpb | 0.585 | -0.402 | 0.703 |

### Table A2: Results of PCA for IQ

| Initial Eigenvalues | | | | | | |
|---|---|---|---|---|---|---|
| **Component** | **Eigenvalue** | **Proportion** | **Cumulative** | | | |
| Comp 1 | 5.189 | 0.864 | 0.864 | | | |
| Comp 2 | 0.379 | 0.063 | 0.928 | | | |
| Comp 3 | 0.250 | 0.041 | 0.969 | | | |
| Comp 4 | 0.107 | 0.017 | 0.987 | | | |
| Comp 5 | 0.041 | 0.006 | 0.994 | | | |
| Comp 6 | 0.031 | 0.005 | 1.000 | | | |
| **PCA Rotation** | | | | | | |
| **Component** | **Variance** | **Proportion** | **Cumulative** | | | |
| Comp 1 | 1 | 0.1667 | 0.1667 | | | |
| Comp 2 | 1 | 0.1667 | 0.333 | | | |
| Comp 3 | 1 | 0.1667 | 0.500 | | | |
| Comp 4 | 1 | 0.1667 | 0.666 | | | |
| Comp 5 | 0.999 | 0.1667 | 0.833 | | | |
| Comp 6 | 0.999 | 0.1667 | 1.000 | | | |
| **PC (Eigenvectors)** | | | | | | |
| **Variable** | **Comp 1** | **Comp 2** | **Comp 3** | **Comp 4** | **Comp 5** | **Comp 6** |
| ps | 0.363 | 0.882 | 0.274 | 0.099 | 0.005 | 0.069 |
| rol | 0.4316 | -0.0460 | -0.1642 | -0.1002 | -0.0707 | -0.8773 |
| voa | 0.3858 | -0.4024 | 0.8085 | -0.1221 | -0.1173 | 0.0830 |
| coc | 0.4201 | -0.0286 | -0.2974 | -0.7007 | 0.3811 | 0.3132 |
| ge | 0.4242 | -0.0989 | -0.3682 | 0.1581 | -0.7380 | 0.3242 |
| rq | 0.4202 | -0.2172 | -0.1419 | 0.6703 | 0.5397 | 0.1246 |

## Appendix B

### Table B1: Unit Root Results

| Variables | IPS | | ADF | |
|---|---|---|---|---|
| | Level | 1st Difference | Level | 1st Difference |
| **LCO2** | 1.297 | -30.047*** | 7.0554*** | 136.156*** |
| **LGDP** | 3.215*** | -20.802*** | 3.5414*** | 73.4329*** |
| **FD** | 4.264*** | -19.613*** | 0.7826 | 63.3547*** |
| **IQ** | -3.716*** | -21.451*** | 9.7427*** | 96.6332*** |
| **FD*IQ** | 1.056 | -13.459*** | 6.8684*** | 52.9785*** |
| **LRE** | -2.365*** | -28.169*** | 6.3747*** | 121.2347*** |
| **LTRADE** | -4.525*** | -29.776*** | 7.3843*** | 130.5037*** |
| **LURB POP** | -9.405*** | -2.511*** | 152.3598*** | 17.6438*** |
| **LIND** | -1.795* | -27.929*** | 3.6785*** | 120.2092*** |