

Financial Development and Carbon Emissions Nexus: Assessing the Moderating Role of Institutional Quality in a Heterogeneous Global Panel

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Abstract

Financial development helps countries to achieve a high growth trajectory. However, its implications for environmental sustainability are rather complex. Rising carbon dioxide emissions, a byproduct associated with financial development activities, pose serious constraints on environmental sustainability. Numerous factors influence emission levels; among them, this study examines how financial development affects carbon dioxide emissions across overall developed and developing countries using the GMM approach over the period 1998-2024. The study relies on a broader global panel data comprising 92 countries, including 55 developed and 37 developing countries. Findings for the global panel, in general, and for developing countries reveal that institutional structures facilitate economic growth but don't preserve the environment. Better institutions minimize market friction and direct credit into traditional fossil-fuel-reliant industrial frameworks. Conversely, the advanced economy sample reveals a critical structural inversion, validating an institutional threshold hypothesis.

The study calls for aggressive integration of environmental standards by developing countries through a green taxonomy framework. Developed countries should eliminate subsidies on non-renewable energy and implement strict carbon adjustment mechanisms. Climate governance should promote environmentally friendly regulatory adaptation from advanced economies to developing nations.

Keywords: Financial Development, Institutional Quality, Carbon dioxide emissions, Moderating Effect, Environmental Kuznets Curve

JEL Classification: Q56, O44, G20

1. Introduction

Carbon dioxide emissions (CO₂) have become a pressing concern worldwide, as it halts the environmental sustainability that is central to the Sustainable Development Agenda. Rising CO₂ is a byproduct of fossil fuels, the rapid pace of industrialization, overreliance on non-renewable energy, and limited availability of renewable energy. It has accelerated global challenges, such as global warming, sea level rise, and extreme weather. Reducing emissions is essential for achieving SDG 13 (Climate Action), which focuses on mitigating and adapting to climate impacts. It also supports SDG 7 (Affordable and Clean Energy), aimed at ensuring access to sustainable energy for all, and SDG 8 (Decent Work and Economic Growth), which promotes inclusive and sustainable economic development. Many studies examined factors influencing CO₂ emissions, including globalization, economic growth, trade openness, and population growth (Zhang, 2011). In recent years, researchers have increasingly focused on financial development (FD) as a factor that can significantly affect CO₂ emissions. The question that is still pending is the direction of this relationship. According to literature (like Eren et al., 2019) the direction depends on many factors which include human capital, energy mix, and the stage of economic development at which a given country is. The impact of FD on environment is mix and mostly it does affect industrial growth, helps in capital accumulation and energy intensive production which all leads to increase in energy consumption which may result in carbon emission. On the other hand, if FD is high enough to be termed as developed financial system, it does affect all three economic factors above but decrease the carbon emission by investing and financing those projects that use energy efficient technology and innovation which helps in reducing carbon footprint and sustainability (Sheraz et al., 2022).

In order to achieve sustainable development goals globally, it is very important to understand the underlying factors and channels through which emissions are being affected. It is believed that nearly 60 percent of total global greenhouse emission is comprised of CO₂¹, the understanding of underlying factors becomes even more important. In the background of the above question, Environmental Kuznets Curve (EKC) hypothesis has gained significant attention in environmental economics. Researchers have tried to explain EKC with updated data and sophisticated econometrics techniques. EKC suggest that environmental degradation initially rises with growing economic activity but as countries reaches a threshold, this environmental degradation start declining. Basically, EKC suggest a energy transition from dirty energy production to cleaner technologies in presence of strong institutions (Grossman & Krueger, 1995).

IQ refers to institutional environment-how much institutions are able to implement what they are created for, like enforcement of contracts, judiciary, public institutions, accountability etc. In same way, IQ explains how effectively laws related to environment are enforced and how projects are regulated to adapt sustainable policies and technologies. Theoretical literature points out that in the presence of strong institutions are able to reach early on maximum peak of EKC curve, after which they will most likely to adapt o cleaner technologies (Hunjra et al., 2020). Countries with weaker institutions faces prolonged period to reach and cause more environment degradation. This insight reinforces the conceptual underpinnings of the current study. IQ is treated as conditional variable in the relationship that is examined between FD and CO₂ emissions. To understand this concept into more detail and to assess which group of countries are likely to be affected by IQ and FD, the data will be divided into two groups of countries along with global data set which will be a reference point for an overall relationship.

Previous studies, while taking EKC hypothesis framework, suggested that FD and IQ are key determinants of carbon emission. FD promote energy consumption through extension of credit to business which promote investment and industrial production, which definitely require an increase energy consumption and thereby emitting carbon in to the atmosphere (Shahbaz et al., 2016; Sadorsky, 2010, 2011). Yuxiang & Chen (2011) showed that FD and IQ also influence environment through technological progress, growth in income and regulatory mechanism. In absence of IQ or institutional oversight, the impact of FD on carbon emission intensifies

¹ <https://www.epa.gov/ghgemissions/overview-greenhouse-gases> and <https://www.climatewatchdata.org/ghg-emissions>

environment degradation by way of promoting energy-intensive industry, un planned urbanization and irregular consumption patterns. The situation where IQ is high and enforcement of law is better, result in reducing the adverse effects of FD by directing the resources towards cleaner technologies and energy transitions (Shahbaz et al., 2016). Based on the above argument, the current study will use IQ as a conditional variable in assessing the CO₂-FD nexus. The current study will likely to examine that, in presence of strong institutions this effect is mitigated or not? The study will also try to assess if in presence of weak institutions, the adverse effect of FD is proven or not.

More specifically, the present study examines the conditional impact of FD on CO₂ emissions, where IQ serves as a conditional variable. Previous studies have carried out the CO₂-FD nexus for a specific region or country (Shahbaz et al., 2013; Kaushal et al., 2024), this study provides a fresh perspective by taking a heterogeneous panel of countries and a comparative assessment of the role of IQ in the FD-CO₂ nexus in group of countries divided by the level of development. It will provide insights into how IQ affect environmental consequences of FD. The study aligns its objectives with the broader agenda of the Sustainable Development Goals. Ultimately, it aims to generate policy-relevant insights to align financial sector expansion with institutional reforms that will likely to generate sustainable economic growth and long-term resilience across countries at different stages of development.

2. Literature Review

The relationship between FD and CO₂ emissions is complex and context-dependent. The results vary across regions, level of development and score of institutional frameworks. A number of studies provide evidence in both directions i.e. how FD can both exacerbate and mitigate environmental degradation Zhang, (2011) sets the stage by demonstrating that financial development, especially financial inter-mediation, significantly escalates carbon emissions in China. This research emphasizes the dominant role of financial inter-mediation over other financial indicators, indicating that the structure of financial development has substantial environmental consequences. In another study by Shahbaz et al. (2013) based on Malaysia, found that FD helps reduce CO₂ emissions in the long run.

For Asian countries, Liu et al. (2023) found that financial development exerts both types of effects-constraining and recovery, on CO₂ emissions for BRI countries. They found the constraining effect dominating the recovery effect for the above countries. In another study by,

Kaushal et al. (2024), they found for 15 developing Asian economies, cross border investment and developing financial sector increases carbon emissions, They also found governance indicators to be moderating his role between emissions and FD. Rachid et al. (2025) found that FD improves environmental outcomes in oil-producing MENA countries but deteriorates them in non-oil-producing ones, highlighting the conditional nature of FD-carbon emission relationship.

Abid (2016) found that in a sample of 25 Sub-Saharan countries, effective governance, through political stability, administrative efficiency, and anti-corruption laws, lowers CO₂ emissions, while weak regulatory enforcement increases it. This study is among those strands of studies that identify IQ as a central unconditional determinant of environmental performance and sustainable development.

In a relatively recent study by Saboori et al. (2024) conducted for Arab and North African Economies, demonstrated that multiple governance dimensions, like rule of law, accountability, and government effectiveness, result in lower levels of CO₂ emissions. This study along with others agrees that FD and IQ can reduce CO₂ emissions. Collectively, these studies suggest that high-quality institutions not only enforce environmental regulations but also able to direct financial resources toward sustainable sectors and green technologies, reinforcing critical role of IQ in achieving the Sustainable Development Goals (SDGs). Beyond the unconditional role of governance, several studies explore how institutional quality moderates the FD-CO₂ emissions relationship. Zheng et al. (2024) confirmed that the effectiveness of eco-friendly state funds depends heavily on governance capacity and public environmental awareness in China.

On the evidence for countries with weaker IQ, Ibrahim et al. (2015) showed that weak governance allows financial expansion to affect environmental degradation positively in Africa. Sheraz et al. (2022) emphasized that good governance helps offset the adverse externalities of globalization by channeling funds into renewable and sustainable sectors. For South Asia, Hunjra et al. (2020) showed that strong institutions mitigate the negative impact of financial expansion on environmental sustainability.

The studies that are cross-country also reinforces the role of IQ in FD and Carbon emission nexus. Wen et al. (2022) found that FD initially increases emissions but reduces them when supported by effective institutions in developing countries. Ghardallou and Abaalkhail (2024)

demonstrated that corruption control and strong legal systems mitigate the pollution effects of financial growth in GCC countries. Recently, Azizov (2026) illustrated that a 1% increase in financial development growth reduces CO₂ emission growth by 3.3%, while renewable energy expansion contributes an additional 1.74% emissions reduction in high-governance countries. IQ tends to amplify the benefits of FD and renewable energy on environmental sustainability. Maharana (2026) identified that financial development increases CO₂ emissions in 5 developed countries and developing countries the impact is gradual and less pronounced.

While prior studies have examined the impact of FD and IQ on CO₂ emissions, most focus on specific countries or regions. The only study by Maharana (2026) investigated the impact of financial development on CO₂ emissions in 5 developed and developing countries; however, it does not provide a comparative analysis between these groups. Evidence on how IQ conditions the impact of FD on CO₂ emissions at a global level remains limited. The current study addresses this gap by providing a comparative global analysis for 92 countries, which include a mix of developed and developing countries. This study also provides the same analysis of two subsamples- for developed and developing countries. Developed countries include 37 countries, and the rest of 55 are among the developing countries. A list of sample countries is provided in the appendix. This type of sample will offer insights into how IQ shapes the environmental consequences of FD and provide policy-relevant guidance for sustainable finance.

3. Data and Methodology

This section contains the theoretical framework, data details, and research methodologies.

3.1 Theoretical Framework

Understanding the dynamic relationship among CO₂ emissions, FD, and IQ has been a central concern in contemporary economic research. The theoretical foundations of this study integrate the Environmental Kuznets Curve (EKC) to explain how financial and institutional mechanisms jointly influence environmental outcomes.

The Environmental Kuznets Curve (EKC), proposed by Grossman and Krueger (1995), postulates a non-linear, inverted U-shaped relationship between economic growth and environmental degradation. At early stages of development, countries tend to experience rising pollution with increasing degrees of industrialization and urbanization. However, beyond a

certain income threshold, environmental quality improves with the adoption of cleaner technologies. Although widely adopted, the EKC has been criticized for oversimplifying the growth-environment nexus by ignoring critical moderating factors such as FD, IQ, and trade (Zhang, 2011). Therefore, this study extends the EKC framework by incorporating FD and IQ as integral components of the environmental transition process.

FD plays a dual role in the economy, initially increasing CO₂ emissions through expanding economic activity but potentially reducing emissions over time as the financial sector matures, and supporting innovation. Yuxiang and Chen (2011) identify that FD affects environmental outcomes by altering capitalization, technology, income, and regulations. The *capitalization effect* may either worsen or improve environmental quality depending on the direction of credit allocation. With strong institutions, FD allocates financial resources for sustainable and clean energy and green innovations. This tends to reduce CO₂, and vice versa. The *technology effect* can promote cleaner innovation if FD promotes transfer and adoption of new technologies, but it may also increase resource use and increase CO₂. The *income effect* may initially raise emissions but improve environmental quality at higher income levels with enhanced demand for cleaner goods and services. The *regulation effect* states that strong regulations can reinforce clean investments that enhance environmental performance when green lending standards are adopted. Financial expansion increases money supply and transaction velocity, thereby stimulating economic growth, which in turn influences CO₂ emissions through two main channels. The *scale effect* and the *wealth effect*. The financial system, by guiding the flow of capital, optimizes or reverses industrial structure, and highly polluting enterprises can be phased out (Sadorsky, 2011). Additionally, FD can increase support for research and adoption of low-carbon technology, which can bring technological innovation and help to curb environmental pollution (Xiong & Qi., 2018).

The IQ dimension plays a critical moderating role in the FD-CO₂ nexus. IQ determines how effectively financial resources are allocated, environmental policies are implemented, and governance inefficiencies such as corruption are controlled (Abid, 2016). Strong institutions enhance policy enforcement, ensure transparency in financial operations, and promote the adoption of environmentally friendly technologies (Sheraz et al., 2022). In contrast, weak institutional frameworks encourage rent-seeking behavior and lax environmental regulations, allowing FD to amplify rather than mitigate CO₂ emissions. Therefore, robust institutions can

redirect financial flows toward sustainable sectors, strengthen compliance with environmental standards, and encourage cleaner production practices.

Integrating these perspectives, this study emphasizes that while FD can initially exacerbate environmental degradation, its impact depends critically on IQ. In economies with strong institutions, FD may enhance environmental outcomes by supporting innovation, enforcing green financing, and ensuring regulatory compliance. Conversely, in contexts of weak governance, FD may lead to unchecked industrial expansion and higher CO₂ emissions.

3.2 Model Specification

This study empirically explores the relationship between FD and CO₂ emissions, with a focus on the role of IQ. The baseline model takes the following functional form;

$$CO_{2it} = \alpha_0 + \alpha_1 CO_{2it-1} + \alpha_2 FD_{it} + \alpha_3 IQ_{it} + \gamma_j Z_{jit} + \varepsilon_i + u_{i,t} \quad (1)$$

In the above equation, CO₂ emissions serve as a dependent variable that serves as a proxy for environmental degradation. FD and IQ are the key explanatory variables that influence CO₂ emissions unconditionally. Z_{jit} represent a set of j variables for the i^{th} country at time t . It includes GDP growth, foreign direct investment (FDI), trade openness (TO), and population growth (PG). $u_{i,t}$ refers to the error term and ε_i denotes country-specific effects.

Empirical evidence suggests that GDP growth, TO, and PG have statistically positive and significant effects on CO₂ emissions in the short and long run (Ohlan, 2015). In contrast, FDI contributes to CO₂ emissions reduction, indicating its potential role in promoting cleaner technologies and environmentally efficient production processes (Zhang & Zhou, 2016).

The study extends the baseline model (1) to assess the moderating role of IQ in the FD-CO₂ emissions nexus as follows:

$$CO_{2it} = \beta_0 + \beta_1 CO_{2it-1} + \beta_2 FD_{it} + \beta_3 IQ_{it} + \beta_4 IQ_{it} * FD_{it} + \delta_j W_{jit} + \mu_i + v_{i,t} \quad (2)$$

The interaction term (IQ*FD) captures the conditional impact of FD on CO₂ emissions. The derivative of model (2) with respect to FD yields the marginal effect of FD on CO₂ emissions as follows:

$$\frac{\partial CO_{2it}}{\partial FD_{it}} = \beta_2 + \beta_4 * IQ_{it} \quad (3)$$

Equation (3) quantifies the unconditional and conditional effect of FD on CO₂ emissions. To account for cross-country heterogeneity, the model is estimated three times: first for the overall sample including both developed and developing countries, second for the sub-sample of developed countries, and third for the sub-sample of developing countries. This approach allows us to examine whether the conditional impact of institutional quality on the FD-CO₂ relationship differs across country groups with varying IQ.

3.3 Data and Estimation Techniques

This study uses annual panel data for 92 countries, including 37 developed and 55 developing economies from 1998 to 2024. The study estimates the moderating role of IQ in the FD-CO₂ relationship for the full sample and sub-samples of developing and developed countries. Table 1 summarizes the variables, their definitions/measurements, and data sources.

Table 1: Variables, Definitions, and Data Sources

Variables	Definitions/Measurement	Data Sources
Carbon Emissions (CO ₂)	Emissions from fossil fuel consumption and production.	WDI, World Bank
Financial Development (FD)	Extent of development in financial institutions and markets.	FD Database, IMF
Institutional Quality (IQ)	A composite index based on six indicators of governance	Author's construction using PCA based on data from WDI, WB
Economic Growth (EG)	The percentage change in real GDP; measured as the size of the economy	WDI, WB
Trade Openness (TO)	Trade as a % of GDP.	WDI, WB
Foreign Direct Investment (FDI)	Net inflows of investment to acquire interest in an enterprise operating in an economy other than that of the investor.	WDI, WB
Population Growth (POP)	Change in resident population over time.	WDI, WB

Following Polat et al. (2020), the authors construct a composite IQ index using Principal Component Analysis (PCA). PCA reduces data dimensions into a composite index without losing vital information. This index aggregates key IQ indicators - rule of law, control of

corruption, government effectiveness, and regulatory quality - into a single index to better represent institutional performance.

The study employs a dynamic panel data model estimated using the two-step system Generalized Method of Moments (System-GMM) estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998). This estimation technique effectively addresses potential issues of endogeneity, omitted variable bias, and unobserved country-specific heterogeneity, which are common in macro-panel analyses. Prior to estimation, the study conducted the Durbin-Wu-Hausman test to check for the problem of endogeneity. This method was developed by Durbin (1954), and Wu (1973), and later refined by Hausman (1978). This test also validates the use of the System GMM method; conventional OLS provides biased estimates in the presence of endogeneity. The null hypothesis states that there is no problem of endogeneity.

4. Results and Discussion

This section contains two sub-sections. The first sub-section provides the basic properties of data and diagnostic tests. The second sub-section documents the empirical findings for the baseline and extended models.

4.1 Descriptive Statistics Analysis and Diagnostic Tests

Table 2 presents the descriptive statistics of the main variables used in this study for overall (92), developed (55), and developing (37) countries from 1998-2024.

Table 2: Descriptive Statistics Across Country Groups

Variables	Groups	Observations	Mean	Std. Dev.	Min	Max
CO ₂	Overall	2484	5.325	5.858	0.021	28.494
	Developed	999	8.763	4.145	3.529	20.469
	Developing	1485	4.417	5.778	0.021	28.494
FD	Overall	2484	0.421	0.225	0.034	0.974
	Developed	999	0.624	0.241	0.063	0.974
	Developing	1485	0.281	0.154	0.034	0.741
IQ	Overall	2484	0.122	0.795	-3.341	2.852
	Developed	999	1.424	0.317	-3.341	1.624
	Developing	1485	-0.196	0.601	-2.591	2.852
GDP Growth	Overall	2484	3.447	3.861	-10.94	14.151
	Developed	999	2.537	3.812	-10.94	13.392
	Developing	1485	4.051	3.78	-10.89	14.151
FDI	Overall	2484	5.703	7.554	-16.438	81.083
	Developed	999	7.531	10.44	-12.657	81.083

	Developing	1485	3.579	5.031	-16.438	59.571
PG	Overall	2484	1.015	1.579	-4.171	9.539
	Developed	999	0.641	0.958	-4.171	5.321
	Developing	1485	1.267	1.332	-2.799	9.539

The overall or global sample is also given, which can be a good reference point to compare both subgroups. The mean CO₂ emissions for the developed group (8.763) are nearly double that of the developing group (4.417). However, the developing group exhibits a much higher maximum value (28.494) compared to the developed group (20.469). This outcome justifies the high energy demand depicting structural legacy requiring higher per capita energy demand by the developed countries in the sample. For the case of developing country sample, the maximum value of CO₂ suggests that there are few countries in sample which are polluting the environment on a massive level. The same is proven by a high standard deviation of 5.778. We may see it as climbing portion of the Environmental Kuznet Curve (EKC) for developing countries. On financial development, developed country sample exhibit the most financially developed sector with a mean value of 0.624 and max score of 0.974. The developing countries have a corresponding score of 0.281 and 0.741, clearly declaring developed countries a winner. It shows that developed countries have highly mature capital market and financial market integration. It also represents difference in structural macroeconomic divide among two group of countries. Since developing countries exhibit a lower financial development, it also explains why our standalone FD and in interaction effect so different. A same situation occurs for Institutional quality, where IQ is high for developed countries and gets negative for developing countries sample. For developed countries the average value is 1.424 which is a strong positive score as compared to -0.196 for developing countries. A minimum score of -3.341 for developing countries also shows in relation to max value a institutional deficit. On the other hand, score for developed countries shows more stability, mature governance framework. A presence of institutional threshold can also be justified for developing countries as the score switches from negative to positive which shows high volatility and at same time evolving legal structures. Another variable-FDI also having the same pattern as for above two variables. A higher mean is observed for developed nations as compared with developing countries. The advance technology and stability in institution attracts capital towards the developed countries. However, a positive value for both captures investment flows to both groups which may highlight towards industrial sector expansion. A macroeconomic convergence theory also seems to be holding when GDP growth is observed for both group of countries. Developing countries are catching up by expanding rapidly which definitely will increase their demand of

energy consumption. The minimum values for both groups are close suggesting global shocks such as global financial crisis of 2008 or the COVID-19 pandemic that broke out in 2019. Both of these events effected the growth prospect of both sample of countries.

In summary, the descriptive statistic shows some structural disparities among the two groups. A high environmental degradation is found in developed countries where CO₂ score was recorded at 8.763, FD score of 0.624 and relatively better governance with a score of 1.424. The developing country exhibits a rather catch-up hypothesis where GDP growth is recorded at 4.051 and population growth of 1.267. However, the same group suffers in governance where IQ is at it minimum score of -0.196 and that also resulted in min FD score of 0.281. This distinct macroeconomic landscape provides the underlying structural explanation for the divergent empirical paths observed in our GMM interactive regressions.

The study conducted DWH test to check whether endogeneity exists in the model. Table 3 reports the results.

Table 3: Results for Endogeneity Test

Test statistics	Model 1	Model 2	Model 3
Durbin χ^2 -Statistics	1.3976** (0.0237)	1.0253*** (0.0087)	0.8519** (.0357)
Wu-Hausman F Statistics	1.3926** (0.0238)	1.0250*** (0.0089)	0.8473** (0.0358)
Notes: Values in parentheses are probability values. *** and ** reflect significance at 10 and 5%, respectively.			

The high value of the DWH test statistic and low probability tend to reject the null hypothesis. Thus, regressors are correlated with the error terms, making OLS estimates unreliable and biased. Thus, the findings confirm that GMM is an appropriate technique.

4.2 Regression Analysis

Table 4 reports findings of the global sample (Columns 2 and 3), developed (Columns 4 and 5), and developing countries (Columns 6 and 7). The global sample reveals the overarching global trend, which serves as the definitive baseline for the entire study. Results from the global sample show high carbon inertia in the sample countries. Global emissions are deeply structural, and past emissions greatly dictate current emissions across the global sample. FD shows a strong positive impact, which may show that unregulated financial markets heavily

prioritize high-yielding, capital-intensive fossil fuel projects globally. For example, FD exerts a positive (polluting) impact on carbon emissions globally. Holding other factors constant, a 1-unit increase in financial development expands carbon emissions by 0.596 to 0.636 units. This indicates that global financial markets are structurally aligned with carbon-intensive projects, heavily channeling credit, liquidity, and capital into fossil fuel generation, infrastructure, and heavy manufacturing.

Table 4: Results of the Baseline and Extended Models

Sample	Overall sample		Developed Countries		Developing Countries	
Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
CO ₂ (-1)	0.9601*** (0.0000)	0.9585*** (0.0000)	0.9748*** (0.0000)	0.9767*** (0.0000)	0.9617*** (0.0000)	0.9601*** (0.0000)
FD	0.5962*** (0.0000)	0.6361*** (0.0000)	0.2375*** (0.0000)	0.2569** (0.0130)	0.2224*** (0.0000)	0.1936** (0.0130)
IQ	-0.0418* (0.0610)	0.0171*** (0.0000)	-0.0038* (0.0863)	-0.0502* (0.0670)	0.0612*** (0.0000)	0.0214*** (0.0000)
FDI	0.0153** (0.0011)	0.0154*** (0.0000)	0.0171*** (0.0012)	0.0196*** (0.0000)	0.0046*** (0.0012)	0.0049*** (0.0000)
GDP	0.0332*** (0.0000)	0.0335*** (0.0000)	0.0491*** (0.0000)	0.0489*** (0.0000)	0.0192*** (0.0000)	0.0189*** (0.0000)
PG	-0.0232*** (0.0001)	-0.0243*** (0.0000)	-0.0533*** (0.0001)	-0.0703*** (0.0000)	0.0451*** (0.0001)	0.0439*** (0.0000)
FD*IQ	-	0.0588*** (0.0000)	-	-0.0845*** (0.0000)	-	0.0470*** (0.0000)
Wald test	6244*** (0.000)	8096*** (0.000)	1704** (0.000)	3521*** (0.000)	3051*** (0.000)	2227*** (0.000)
AR(1)	-2.013** (0.0169)	-2.2358** (0.0254)	-2.801*** (0.0026)	-2.9082*** (0.0036)	-0.0786** (0.0260)	-1.3525** (0.0170)
AR(2)	-0.8556 (0.2659)	-0.9098 (0.3629)	-1.0459 (0.1802)	-1.1498 (0.2502)	-0.0752 (0.0856)	-0.1025 (0.9184)
Sargan Test	59.0541 (0.0780)	61.0575 (0.0854)	32.3612 (0.7654)	34.6435 (0.8680)	42.369 (0.1158)	46.2915 (0.1967)
Note: The dependent variable is carbon dioxide emissions. ***, **, and * show significance at 1%, 5%, and 10% respectively.						

IQ has different results in both regressions: where the interaction term is absent, its sign is negative and significant at the 10% level of significance, whereas in the second model with the interaction term it becomes positive and significant at the 1% level. It shows an ambiguous effect on its own-this shifting behavior emphasizes that IQ cannot reduce emissions on its own; it must work through the financial markets via the interaction term. The change of sign also represents the fact that IQ works with financial market especially when there is a need of

enforcement of financial contracts (Levine, 1997). IQ area of influence becomes stronger when it join in hands with FD. For other variables-FDI and GDP, they both exert positive effect on CO₂ implying that both variables create a need for expansion which in turn increase the need for energy consumption, thereby contributing positively towards carbon emission. Interestingly PG is negative in both models which may indicate the heavy influence of developing countries in the sample. The population which also constitute urbanization also outweighs the developed countries which may help explain the negative impact. PG also dilutes capital or expands rural communities which explain less industrialization. There are segments of developing countries where urbanization is high but when observed in a sample their weight becomes diluted.

The interaction term in the regression is positive and significant which shows that FD and IQ jointly contribute positively towards carbon emission. In a global sample it indicates that FD and IQ jointly degrade environment. It may be because of the reason that mostly institutional framework is designed to reduce risk in commercial activities and the strict rules regarding legal, property rights and bureaucratic to name a few, forces capital to informally go in projects that are still traditional energy consuming and fossil fuel intensive projects. It shows then the amplification effect. We already discussed the highly positive effect of FD in a standalone manner, positive interaction then means that rising IQ exacerbates the polluting nature of FD in our global sample. The positive effect through FD can also be understood from the fact that on a global level, to attract capital and to optimize ease of doing business, most IQ characters like property rights protections, legal framework, and contractual enforcement are designed to reduce credit market risk and maximize GDP growth. Consequently, the commercial banks will increase the lending and since carbon heavy investments remain highly profitable, the same financial institutions will inadvertently increase lending to accelerate the flows of liquid capital into dirty industries rather than strive to cater for more environmental friendly projects. Our results for global sample are partial agreement to that of Shahbaz et al (2016).

Both models of the global sample are diagnostically valid where the AR(2) is insignificant at 5% level which means absence of no second order auto correlation and Sargan test insignificance at 5% also proves the validity of instruments used.

To see more detailed results and the effect of independent variables on carbon emissions, the study divided the sample into two groups-Developed and developing countries- which may help to understand the results better and capture the heterogeneity of countries in the global

sample. Columns (4) and (5) in Table 3 present the results for developed countries in columns 4 and 5. The results show high environmental inertia, as was the case for the global sample. Past emissions strongly dictate current emissions, which may mean environmental damage accumulates and takes a long time to reverse. Financial development increases carbon emissions in both models, which implies the financial sector is currently funding energy-intensive, highly polluting industries. In other words, the result shows that when left completely unmoderated, financial systems and liquid capital markets still aggressively channel substantial credit lines into standard, energy-intensive commercial sectors. An interesting result is observed for IQ, in which for both regressions the impact is negative. The impact is weakly significant at the 10 percent level of significance, which may raise questions about its efficacy; however, when the interaction term is considered, which moderates the IQ with FD, the result seems justified.

Standalone IQ exerts a negative impact on carbon emissions. The negative sign implies that the core governance architecture in developed countries—characterized by strict environmental legislation, rule of law, transparent corporate disclosures, and lower corruption—directly forces a baseline mitigation of carbon emissions by compelling industries to comply with state environmental benchmarks.

The interaction term comes out to be negative in our regression which is significant at 5 percent level of significance. The interaction term shows that institutional quality exacerbates the polluting effect of FD. In other words, IQ acts as a mitigating effect towards the FD polluting contributing role. What FD can do irresponsible, IQ is there as a watchdog to keep an eye on the FD activities. In same regression a positive FD indicate that FD contribute positively towards carbon emission and may show irresponsible behavior of financial markets, however in interaction with IQ, the strong legal framework, environmental laws and governance mechanism help deviate major financial capital away from dirty industries. It may compel the financial institutions to invest in green technology making them more responsible socially and environmentally friendly. Our result also suggests that in comparison to global sample, it seems developed countries have achieved/crossed a certain threshold, which may be called as institutional green threshold, which have made their financial system more responsible and adapting green banking taxonomies, more rigorous carbon auditing practices and environmental laws do alter their investment behavior. That's is why developed countries financial institutions are working towards green finance and sustainable ESG framework.

The variable PG is not only negative but also significant which is same to the case we found for global sample. For developed countries it represents a entire demographic shift coupled with technological shift. The developed countries have highly dense urban areas but they were designed with energy efficient measures. Further urbanization is and population growth occurs along side strict environmental rules and building codes. The public transport system is also efficient, allowing population to use fewer private vehicles and use public transport. The conversion of public transport on electric mode also reduced carbon emissions. All the above measures helps explain lower per capita emissions. Cross-border capital inflows FDI drive up emissions via the Scale Effect. In developed countries, incoming FDI often uses or target highly automated digital machinery or operations which often uses high-energy. Although these facilities may use state of the art technology or methods, their immense use created heavy demand for energy that can result in carbon emission.

The last two columns of the table present the result for developing countries sample. In this regression, FD is positive which is the same result we got for developed countries. A one-unit increase in FD leads to a 0.1936-unit increase in carbon emissions. This indicates the financial sector lending to low cost but high emission industries which increases carbon emissions. When we compared it to developed sample, where IQ was reducing the effect of FD activities, the stand-alone IQ is also positive which indicate low score for IQ. It represents weak contract enforcement and lower regulatory infrastructure. This also represent growth first institutional orientation and validity of EKC hypothesis partially, where the first objective is to grow and consequently the bureaucratic and legal laws are designed to facilitate industrial output, improve business conditions, ease of doing business and accelerate economic growth. All of these steps inherently increase carbon emissions. PG in developing countries is also positive which is in sharp contrast to what we found for PG in developed country sample. It indicates the demographic shifting of population and growth of population without necessary checks. This increases the urbanization without bounds and expanding the energy requirement. The population increased requirement for transportation also increase and due to non-affordability and less public transport they resort to those vehicles which are old technology. All of the above explains the increase of PG with positive carbon emission.

For developing countries sample the interaction term is positive and significant showing that IQ amplifies the carbon emitting role of FD. As for developed country sample, to mitigate the carbon emitting role of FD, strong legal, regulatory and contract enforcement law as ensure a

safer, lower risk environment for commercial banks to aggressively fund green project or at least prohibit them to invest in high emission projects. However our result for interaction term shows that FD and IQ prioritize economic survival and growth thereby jointly contributing towards carbon emissions. It represents a classic case of structural priorities. The stability that comes with IQ in financial markets, it drastically reduces risks for commercial banks and private investors. This will increase credit demand, that is increasing FD score. Since the environmental regulations are weak, in the name of institutional efficiency the same financial institutions feel it easier to fund highly polluting industrial units and fossil fuel projects. This will certainly increase carbon emissions. It also shows that unlike developed nations, the developing countries as a group has not reached that threshold in IQ that will compel them to regulate and be a watchdog for financial sector. This causes the FD*IQ interaction to turn positive, actively decoupling financial markets from ecological degradation.

The variable FDI is also positive and significant which shows that increase in FDI increased Carbon emissions. It supports the pollution heaven hypothesis. Due to weak IQ and emphasis on growth, many multinational businesses relocate their carbon dense industry and heavy manufacturing operations to the developing countries. It reduces their operational costs and more lenient environmental laws also helps them to save on that front. The scale effect is smaller in developing countries as compare to developed countries data (0.0049 vs 0.0196); which indicate the raw energy intensity per unit of foreign project is less. GDP is also increasing the carbon emission showing the growth is a result of some not so environmentally friendly projects. It also validates the presence of Kuznet curve climb as explained early in the paper. For PG, unlike developed nations where population growth drops emissions due to smart efficiency, population growth in developing nations has a strong, significant positive impact. In developing countries, population expansion triggers rapid, uncoordinated urbanization. This creates immense demand for residential power, basic transport networks, and localized infrastructure, almost all of which are met via cheap, carbon-heavy energy sources. Similar to the global sample and developed countries, the diagnostic tests for the developing sample are also satisfactory and show the validity and exogeneity of the instruments.

Next, the authors estimate the marginal effects of FD on CO₂ at the minimum, mean, and maximum values of IQ. Table 5 documents the marginal effects.

Table 5: Marginal Effects of Financial Development on Carbon Emissions

Level of IQ	Global	Developed	Developing
Minimum	0.4397	0.5392	0.0718
Mean	0.6433	0.1366	0.1844
Maximum	0.8038	0.1197	0.3276
Note: All the marginal effects are significant at the 1% level.			

Column (1) in Table 5 reports the marginal effects of the global sample. The result shows that even when institutional quality is at its global absolute minimum, expanding financial markets still significantly increases carbon emissions. At the maximum level, it signifies the amplification paradox-when global institutions are at their strongest, their business-facilitating nature makes credit generation much more efficient, accelerating legacy industrial pollution to its highest rate.

The marginal effects for developed countries reported in Column (2) are positive. When governance standards drop to their absolute lowest in developed countries, the dampening effect disappears. Financial expansion behaves in an unmitigated manner, heavily driving up carbon emissions. When institutional quality is fully maximized, the polluting effect of financial markets is heavily suppressed. Strong green tax structures, carbon frameworks, and strict corporate governance effectively guide credit flows away from heavy polluters. Compared to that, when institutional quality is at its absolute minimum in developing countries, expanding financial development has a muted but still positive effect (+0.0718) on carbon emissions.

In the presence of weak governance, the credit expansion remains low since investor do not trust that their investment will be returned to them or return will be ensured. When governance reaches a high score in a sample of developing countries, the carbon emission also reaches at a level of 0.3276. This result supports the first enabler mechanism, which mean stable financial infrastructure or institutions extends credit to industries with high carbon footprint and non-green industrial output. For the developing countries sample, the marginal effect exhibits interesting outcome. When IQ score increases from its minimum to max the effect to f FD on carbon emission approximately increases from 0.0718 to 0.3276. this clearly indicate previously identified industrial enabler situation-reducing the regulatory requirement and focus on growth expansion at an early stage, for carbon heavy industries. To overcome this weakness, the Central banks of the developing countries should increase regulatory framework and

introduce macroprudential credit steering policies. This will bind the commercial banks to extend loans to business unit adhering to more environmental laws.

For developed countries, the marginal effects are showing good adherence to laws governing the environment. When IQ is maximized, the marginal effect of FD is suppressed to a lower level of 0.1197. This outcome supports the developed governance systems that checks on the capital market institutions and if necessary, changes their course towards more environmentally friendly projects. Our results are closely related to Kim et al. (2022), Lv et al. (2021), Sadorsky (2011) and partially with Sadorsky (2013) and Shahbaz & Lean (2012) where they showed that financial development does increase energy consumption and urbanization in Tunisia.

In summary, for the global sample, FD and IQ are positively associated with carbon emission because of mainly growth-oriented projects. For the developing countries the result is same for the above variables along with PG, FD, IQ and GDP. The developing countries also seem to drive the result of global sample, which may be due to the heavy percentage of developing countries compare to developed. The developed countries sample, in that context, seems to be an “outlier”. It also proves that once a mature threshold is crossed, its IQ reverses roles and begin to act as a check on the operations of its financial activities.

5. Conclusion and Policy Recommendations

This study investigated the impacts of financial development, institutional quality, and their interactive effect on carbon emissions. In order to carry out the analysis, the study took a sample of 92 countries, which was divided into two sub-samples that represent developed countries and developing countries. The developed countries include 37 countries and the developing countries include 55 countries. The list of each group is given in the appendix. The main contribution of the study lies in the interaction term FD x IQ, which is analyzed through three sample data. The mapping of the marginal effect introduces us to some concrete outcome of the study, which shows that for baseline model that consist of global scale, institutional framework act as a facilitator rather than act as shield for ensuring implementation of environment related rules. Stricter institutional rules but weak enforcement compel financial institutions to secure themselves but direct credit towards project using high fossil fuel and capital-intensive projects that will definitely increase carbon emissions. The same result was found for developing countries as well. For developed countries sample, it shows a presence of threshold hypothesis where early-stage institutional quality may prioritize economic

expansion but once it reaches a mature governance framework, the regulatory framework will ensure adherence to the rules that are more environmentally friendly. In developed countries, sophisticated institutional oversight successfully enforces green mandates, carbon pricing compliance, and ESG metrics, effectively compelling financial markets to decouple from carbon-intensive investments.

Our results also suggest FD significantly increases carbon emissions across all groups. This shows that FDI does contribute towards economic activity and an increase in emissions of carbon. An interesting relation can be determined between FDI and IQ. In the developing country sample and global sample, IQ is positively associated with carbon emissions, which suggests institutional score is not high enough to implement environmental regulations. As for developed country sample, it represents a negative relationship indicating that strong institutions help mitigate the environmental impact of FD.

It is suggested that developed nations must adhere to a strict carbon-border adjustment mechanism and cross-border inflows must be pegged to zero-emission digital and industrial grids. For Governments in developing nations, it is suggested to integrate environmental laws into core banking values. Institutional quality should be improved not only with a perspective of contract enforcement and bringing market stability, but also be tied to a green taxonomy framework. It will then act as a filter that blocks low-quality and carbon-heavy credit allocations. International global climate governance institutions should facilitate the exporting of green regulatory frameworks from advanced economies to developing nations. That process will help developing economies to reach closely to advanced economies in terms of environmental technology, which will definitely reduce the time require for developing economies to reach their own environmental-institutional turning point.

6. Limitations and Future Research

The current study is unique in the sense that as far as comprehensive literature is searched, no study was found that examined the carbon-finance nexus as this study has carried out, especially with three sub-samples. However, in carrying out this study there are some limitations that we faced and working on these limitations may help to identify future research in this area. For example, a primary limitation of the study is the absence of aggregated macro indicators for the core variables like FD, IQ, and CO₂. These aggregate indicators smooth over nuanced sector-level variations, which dampens the variations across distinct economic sectors,

for example, varying energy intensities found within industrial manufacturing, digital data infrastructure, transportation, and agriculture. It is therefore suggested for future research that disaggregated data may be used for future research to better capture this limitation. In this regard green bond issuance or specialized sustainability indicators can be used to evaluate the environmental impact of target-specific liquid credit. Disaggregating institutional benchmarks into standalone indices for environmental rule of law versus baseline economic contract enforcement will offer deeper clarity on regulatory behavior. On the estimation side, it is suggested to use threshold models or non-linear estimation techniques to estimate the inflection points where a country's institutional score switches from a growth-first to environmental protection tool. Another suggestion would be to include some political economy factors in assessing the role of FD and carbon emission nexus.

7. Appendix

Developed Countries							
1	Australia	10	Finland	19	Japan	28	Norway
2	Austria	11	France	20	Korea, Rep.	29	Portugal
3	Belgium	12	Germany	21	Latvia	30	Singapore
4	Canada	13	Greece	22	Lithuania	31	Slovak Republic
5	Croatia	14	Hong Kong SAR	23	Luxembourg	32	Slovenia
6	Cyprus	15	Iceland	24	Macao SAR	33	Spain
7	Czechia	16	Ireland	25	Malta	34	Sweden
8	Denmark	17	Israel	26	Netherland	35	Switzerland
9	Estonia	18	Italy	27	New Zealand	36	United Kingdom
						37	United States

	Developing Countries										
1	Albania	11	Bulgaria	2	Egypt	3	Jordan	41	Nepal	51	Thailand
2	Algeria	12	Cambodia	2	Ethiopia	3	Jamaica	42	Oman	52	Tunisa
3	Argentina	13	Cameroon	3	Fiji	3	Kazakhstan	43	Pakistan	53	Türkiye
4	Azerbaijan	14	Chad	4	Georgia	4	Kenya	44	Philippine	54	Uzbekistan
5	Bahrain	15	Chile	5	Ghana	5	Malawi	45	Poland	55	Vietnam
6	Bangladesh	16	China	6	Hondorus	6	Malaysia	46	Romania		
7	Belarus	17	Colombia	7	Hungary	7	Mali	47	Russia		
8	Bosnia	18	Comoros	8	India	8	Mexico	48	Sri Lanka		
9	Brazil	19	Costarica	9	Indonesia	9	Morocco	49	South Africa		
10	Brunei	20	Dominica	10	Iran	10	Nigeria	50	Tajikistan		

References

- [1] Abid, M. (2016). Impact of economic, financial, and institutional factors on CO₂ emissions: Evidence from Sub-Saharan Africa economies. *Renewable and Sustainable Energy Reviews*, 45, 635–645. <https://doi.org/10.1016/j.jup.2016.06.009>
- [2] Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics*, 68(1), 29–51. [https://doi.org/10.1016/0304-4076\(94\)01642-D](https://doi.org/10.1016/0304-4076(94)01642-D)
- [3] Azizov, A. (2026). Does Financial development reduce emissions? The role of renewable energy. Evidence from high-governance economies. *International Journal of Energy Economics and Policy*, 16(2), 730. <https://doi.org/10.32479/ijeep.22164>
- [4] Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, 87(1), 115–143. [https://doi.org/10.1016/S0304-4076\(98\)00009-8](https://doi.org/10.1016/S0304-4076(98)00009-8)
- [5] Durbin, J. (1954). Errors in variables. *Review of the International Statistical Institute*, 22(1/3), 23–32. <https://doi.org/10.2307/1401917>
- [6] Eren, B. M., Taspinar, N., & Gokmenoglu, K. K. (2019). The impact of financial development and economic growth on renewable energy consumption: Empirical analysis of India. *Environmental Science and Pollution Research*, 26(24), 24509–24519. <https://doi.org/10.1016/j.scitotenv.2019.01.323>
- [7] Ghardallou, W., & Abaalkhail, L. (2024). The Moderating Effect of Institutions on the Relationship between Financial Development and Environmental Quality: Evidence from GCC countries. FINANCIAL DEVELOPMENT AND ENVIRONMENTAL QUALITY. *Journal of Scientific & Industrial Research*, 83(8), 836–844. <https://doi.org/10.56042/jsir.v83i8.8926>
- [8] Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics*, 110(2), 353–377. <https://doi.org/10.2307/2118443>
- [9] Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica*, 46(6), 1251–1271. <https://doi.org/10.2307/1913827>
- [10] 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. <https://doi.org/10.3390/su12093805>
- [11] Ibrahim, M. H., & Law, S. H. (2015). Institutional quality and financial development in Africa. *Economic Modelling*, 44, 54–66.

- [12] Kaushal, L. A., Chauhan, A. S., Dwivedi, A., & Bag, S. (2024). The governance factor: Mitigating carbon emissions through FDI and financial development in emerging Asian economies. *Journal of Environmental Management*, 367, 121740. <https://doi.org/10.1016/j.jenvman.2024.121740>
- [13] Kim, D. H., Wu, Y. C., & Lin, S. C. (2022). Carbon dioxide emissions, financial development and political institutions. *Economic Change and Restructuring*, 55(2), 837–874. <https://doi.org/10.1007/s10644-021-09331-x>
- [14] Lv, C., Shao, C., & Lee, C. C. (2021). Green technology innovation and financial development: Do environmental regulation and innovation output matter? *Energy Economics*, 98, 105237. <https://doi.org/10.1016/j.eneco.2021.105237>
- [15] Maharana, A. K. (2026). Does Financial Development Improve Environmental Sustainability? Comparative: Evidence from Developed and Developing Countries Among the World's Five Largest Economies. *Sustainable Development*, 1–9. <https://doi.org/10.1002/sd.70826>
- [16] Liu, C., Xu, J., & Zhao, J. (2023). How does financial development reduce carbon emissions: Evidence from BRI countries. *Environmental Science and Pollution Research*, 30(10), 27227–27240. <https://doi.org/10.1007/s11356-022-24105-2>
- [17] Rachid, S., Nasr, M., & Boukhatem, J. (2025). Dynamic interaction between financial development, institutional quality and environmental conditions: New insights from MENA region. *Development and Sustainability in Economics and Finance*, 6, 100050. <https://doi.org/10.1016/j.dsef.2025.100050>
- [18] Saboori, B., Mahdavian, S. M., & Radmehr, R. (2024). Assessing the environmental impact of institutional quality at aggregate and disaggregate levels: The role of renewable and non-renewable energy consumption and trade in MENA countries. *Sustainable Environment*, 10(1), 2426833. <https://doi.org/10.1080/27658511.2024.2426833>
- [19] Sadorsky, P. (2011). Financial development and CO2 emissions in Central and Eastern Europe. *Energy Policy*, 39(2), 999–1006. <https://doi.org/10.1016/j.enpol.2010.11.034>
- [20] Sadorsky, P. (2013). Do urbanization and industrialization affect energy intensity in developing countries? *Energy Economics*, 37, 52–59. <https://doi.org/10.1016/j.eneco.2013.01.009>
- [21] Shahbaz, M., & Lean, H. H. (2012). Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia. *Energy Policy*, 40, 473–479. <https://doi.org/10.1016/j.enpol.2011.10.050>

- [22] Shahbaz, M., Shahzad, S. J. H., Ahmad, N., & Alam, S. (2016). Financial development and environmental quality: The way forward. *Energy Policy*, 98, 353–364. <https://doi.org/10.1016/j.enpol.2016.09.002>
- [23] Ohlan, R. (2015). The impact of population density, energy consumption, economic growth, and trade openness on CO2 emissions in India. *Natural Hazards*, 79(2), 1409–1428. <https://doi.org/10.1007/s11069-015-1898-0>
- [24] Polat, O. (2020). Measuring quality of governance in Turkey: A composite governance index. *Fiscaoeconomia*, 4(1), 51–60.
- [25] Shahbaz, M., Solarin, S. A., Mahmood, H., & Arouri, M. (2013). Does financial development reduce CO2 emissions in the Malaysian economy? A time series analysis. *Economic Modelling*, 35, 145–152. <https://doi.org/10.1016/j.econmod.2013.06.037>
- [26] Shahbaz, M., Shahzad, S. J. H., Ahmad, N., & Alam, S. (2016). Financial development and environmental quality: The way forward. *Energy Policy*, 98, 353–364. <https://doi.org/10.1016/j.enpol.2016.09.002>
- [27] Sheraz, M., Deyi, X., Sinha, A., Mumtaz, M. Z., & Fatima, N. (2022). The dynamic nexus among FD, renewable energy and carbon emissions: Moderating roles of globalization and institutional quality across BRI countries. *Journal of Cleaner Production*, 343, 130995. <https://doi.org/10.1016/j.jclepro.2022.130995>
- [28] Wen, Y., Li, P., & Zhou, J. (2022). Financial development, institutional quality, and environmental degradation: Dynamic panel analysis from developing countries. *Environmental Impact Assessment Review*, 93, 106713.
- [29] Wu, D. M. (1973). Alternative tests of independence between stochastic regressors and disturbances. *Econometrica: Journal of the Econometric Society*, 41(4), 733–750. <https://www.jstor.org/stable/1914093>
- [30] Xiong, L., & Qi, S. (2018). Financial development and carbon emissions in Chinese provinces: A spatial panel data analysis. *The Singapore Economic Review*, 63(02), 447–464. <https://doi.org/10.1142/S0217590817400203>
- [31] Yuxiang, K., & Chen, Z. (2011). Financial development and environmental performance: Evidence from China. *Environment and Development Economics*, 16(1), 93–111. <https://doi.org/10.1017/S1355770X10000422>
- [32] Zhang, Y.-J. (2011). The impact of financial development on carbon emissions: An empirical analysis in China. *Energy Policy*, 39(4), 2197–2203. <https://doi.org/10.1016/j.enpol.2011.02.026>

- [33] Zhang, C., & Zhou, X. (2016). Does foreign direct investment lead to lower CO2 emissions? Evidence from a regional analysis in China. *Renewable and Sustainable Energy Reviews*, 58, 943–951. <https://doi.org/10.1016/j.rser.2015.12.226>
- [34] Zheng, X., Liu, Y., & Xu, C. (2024). Financial innovation, institutional efficiency, and environmental outcomes: Evidence from global economies. *Environmental Research*, 239, 117083.