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Institutional Quality, Income, and FDI: Unravelling Their Impact on Environmental Degradation in Developing Economies

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Abstract

This study investigates the role of institutional quality in shaping the relationship between income, FDI, and environmental degradation in developing economies, using a balanced panel dataset of 87 countries from 2000 to 2019. Adopting the Generalized Method of Moments (GMM) estimator, the study explores the Environmental Kuznets Curve (EKC) hypothesis. It examines how institutional factors, such as government effectiveness and the rule of law, influence environmental outcomes. The findings confirm the EKC hypothesis, demonstrating that income initially increases CO2 emissions but eventually leads to reductions as income rises. Institutional quality plays a critical role in mitigating environmental degradation, with stronger governance structures significantly reducing emissions by promoting the enforcement of environmental regulations and facilitating the adoption of clean technologies. The results also reveal that FDI contributes to environmental degradation in countries with weak institutions but can mitigate emissions when supported by effective governance.

Furthermore, energy consumption, particularly from non-renewable sources, exacerbates pollution, underscoring the need to transition to renewable energy. The study highlights the importance of institutional reforms, cleaner energy investment, and environmentally responsible FDI in achieving sustainable development in developing countries. The findings provide valuable insights for policymakers balancing income with environmental sustainability.

Keyword: Income, FDI, Institutional Quality, CO2, Energy Consumption, GMM

Introduction

Environmental degradation remains one of the most pressing global issues of the 21st century, particularly in the context of developing countries. These nations, which are often characterized by rapid industrialization and economic expansion, face the challenge of aligning their growth ambitions with the principles of sustainable development. This problem is most clearly reflected in the rise of carbon emissions, a primary driver of global warming and climate change. Carbon emissions contribute to the destabilization of ecological systems and threaten the livelihoods and health of millions of people worldwide, especially in the most vulnerable regions. The need to address these environmental issues is recognized globally through frameworks such as the Sustainable Development Goals (SDGs), which specifically target ecological sustainability, climate action, and the promotion of clean energy (World Bank, 2019). For developing nations, however, balancing economic growth with environmental preservation remains an arduous task, as these countries collectively contribute a substantial share of the world's CO2 emissions, a situation exacerbated by their reliance on carbon-intensive industries (Sarkodie and Strezov, 2019; Apergis and Ozturk, 2015).

A significant body of research has explored the causes and consequences of environmental degradation. However, the role of institutional quality in addressing this issue has gained increasing attention in recent years. Strong institutions are recognized as essential for enforcing environmental regulations, promoting clean technologies, and ensuring the sustainable use of natural resources. High institutional quality, characterized by robust governance structures, accountability, and transparency, is key to the effective implementation of environmental policies (Acemoglu et al., 2014; Dasgupta et al., 2006). Countries with strong institutional frameworks are better equipped to manage the environmental consequences of economic growth, as they can effectively regulate industries, enforce environmental laws, and promote the adoption of cleaner technologies. Conversely, weak institutions—marked by corruption, lack of regulatory enforcement, and governance inefficiencies often exacerbate pollution and environmental degradation. In many developing countries, institutional inefficiencies remain pervasive, undermining efforts to reduce CO2 emissions and protect the environment (Ali et al., 2019; Das and Zhang, 2021).

The rule of law and government effectiveness are critical components of institutional quality that directly impact environmental outcomes. The rule of law ensures that environmental regulations are sustained, creating a legal framework that holds industries accountable for their environmental impact. Government effectiveness, on the other hand, refers to the ability of the state to implement policies efficiently and to deliver public goods and services, including environmental protection measures. Without these institutional elements, environmental degradation persists unconstrained as industries exploit weak regulatory environments to prioritize economic gains over sustainability (Nguyen and Ha, 2021). The link between institutional quality and environmental degradation is thus a crucial area of inquiry, especially in developing countries where governance structures cannot often enforce environmental policies effectively.

FDI is another major factor influencing environmental outcomes in developing economies. While FDI is widely regarded as a key driver of economic development, its relationship with environmental degradation is complex and multifaceted. On one side, FDI can introduce

advanced technologies that enhance production efficiency and reduce industries' environmental footprint. In this respect, FDI has the potential to serve as a mechanism for sustainable development by promoting cleaner production processes and contributing to the growth of green industries (Zakaria and Bibi, 2019; Cole et al., 2008: Imam et al., 2024). On the other hand, FDI can also exacerbate environmental harm, particularly in countries with weak regulatory environments. When institutional frameworks are inadequate or poorly enforced, foreign investors may prioritize profit maximization over environmental sustainability, leading to increased pollution and resource depletion (Zhao et al., 2020). This dynamic, often called the "pollution haven hypothesis," suggests that firms in countries with stringent environmental regulations may relocate their polluting activities to countries with weaker environmental standards, thereby increasing CO2 emissions in the host country.

The quality of institutions in the host country largely mediates the effect of FDI on environmental degradation. Countries with strong institutional frameworks can better ensure that FDI contributes positively to environmental sustainability, as foreign firms must adhere to local environmental regulations and can be held accountable for their environmental impact. In contrast, foreign investors may exploit regulatory loopholes in countries where institutions are weak, contributing to environmental degradation through unsustainable practices (Nguyen and Ha, 2021). This highlights the critical role of institutional quality in shaping the environmental consequences of FDI, an area that remains underexplored in the context of developing economies.

Energy consumption is another key determinant of environmental degradation, particularly in developing countries heavily reliant on non-renewable energy sources such as coal, oil, and natural gas. The growth of energy-intensive industries, combined with rising consumer demand for energy, has significantly increased CO2 emissions in many developing countries (Sadorsky, 2011; Shahbaz et al., 2013). Non-renewable energy consumption is closely tied to economic growth, as expanding economies require greater energy inputs to fuel industrial activities and transportation. However, this reliance on fossil fuels has severe environmental consequences, as burning coal and oil is the largest contributor to greenhouse gas emissions globally.

In contrast, renewable energy consumption (REC) has been shown to have a positive effect on reducing CO2 emissions, offering a viable pathway towards environmental sustainability (Yuan et al., 2021). The transition from non-renewable to renewable energy sources—such as wind, solar, and hydropower—has the potential to reduce the carbon intensity of energy production significantly. Nevertheless, the adoption of renewable energy remains slow in many developing countries, hindered by institutional barriers, high infrastructure costs, and limited technological capacity. Strong institutions are crucial for overcoming these barriers, as they can facilitate the necessary investments in renewable energy infrastructure and create policies that incentivize using clean energy sources (Ali et al., 2019). Thus, the role of institutional quality in promoting renewable energy consumption is a critical area of study, especially in developing economies where the need for sustainable energy solutions is most urgent.

Despite the growing recognition of institutional quality's importance in environmental outcomes, there remains a lack of comprehensive studies that integrate the role of

institutions with income, energy consumption, and environmental degradation in developing countries. Existing research has often focused on the interaction effect of institutional quality and GDP growth and individual variables, such as FDI or energy consumption, without fully accounting for the moderating role of institutional quality.

This study seeks to fill these gaps by investigating the role of institutional quality in shaping the impact of income, FDI, energy consumption, and environmental degradation in developing countries. Using a balanced panel Generalized Method of Moments (GMM) estimator, this study offers a comprehensive analysis that integrates institutional quality into the discourse on environmental sustainability. By focusing on a large sample of developing countries, this research provides new insights into how institutional reforms can support the transition to sustainable energy consumption and mitigate the environmental impact of economic growth.

Our contribution to the literature is fourfold: First, we retest the validity of the environmental Kuznets curve EKC on the panel of 87 countries. Second, we explore the moderating role of institutional quality in the environmental impact of income and FDI, focusing on a large sample of developing nations. Third, we examine the effects of variable energy consumption (REC and EC) on environmental degradation. Fourth, we examine institutional reforms' short- and long-term impact on environmental sustainability, providing practical implications for policymakers. Finally, this study applies the two-step GMM estimator to panel data from 2000 to 2019 across 87 developing countries, addressing critical econometric issues such as serial correlation, heteroscedasticity, and endogeneity, thereby producing robust results.

The remainder of this paper is organized as follows: Section 2 reviews the relevant literature, Section 3 outlines the data and methodology, Section 4 presents the empirical results and discussion, and Section 5 concludes with policy recommendations.

Review of Related Literature

Environmental Kuznets Curve Hypothesis

The EKC hypothesis remains one of the most widely discussed frameworks in environmental economics for examining the relationship between economic growth and environmental degradation. Initially inspired by Kuznets' (1955) research on income inequality, Grossman and Krueger (1995) extended the concept to environmental degradation, suggesting an inverted U-shaped relationship between per capita income and environmental degradation. According to this hypothesis, environmental degradation increases during the early stages of economic development as industrial activities expand and energy consumption rises. However, environmental degradation declines beyond a certain income threshold as economies transition to less resource-intensive industries, adopt cleaner technologies and implement stricter environmental regulations (Stern, 2004; Panayotou, 1993).

Recent empirical studies have revisited the EKC hypothesis, testing its validity across various countries and regions. Evidence from developed economies has largely supported the EKC, where environmental quality improves as countries achieve higher income levels, primarily due to advanced technologies, regulatory reforms, and increased awareness of environmental sustainability (Sarkodie & Strezov, 2019). For instance, Nejat et al. (2018) found that the shift towards renewable energy and energy-efficient technologies significantly reduced CO2 emissions in high-income countries, consistent with the EKC hypothesis. In contrast, the EKC hypothesis has produced mixed results in developing economies. Many developing countries continue to rely heavily on fossil fuels for their energy needs, and the

absence of strong environmental governance and regulatory frameworks often leads to sustained increases in CO2 emissions, even as per capita income rises (Shahbaz et al., 2013; Alvarado et al., 2021). Studies such as Dinda (2018) argue that the inverted U-shaped relationship posited by the EKC is less pronounced in developing countries, where economic growth often prioritizes industrial expansion over environmental sustainability. Furthermore, Kivyiro and Arminen (2019) found that many African countries have yet to reach the turning point at which economic growth leads to environmental improvements, primarily due to the absence of robust environmental policies and the continued dependence on non-renewable energy sources.

Institutional quality has been identified as a critical factor in determining whether countries achieve the turning point in the EKC. Institutional quality, including governance effectiveness, regulatory enforcement, and anti-corruption measures, can significantly influence a country's ability to reduce environmental degradation as its economy grows (Omri et al., 2019). For instance, Liu and Zhang (2021) suggest that countries with stronger institutions are more likely to experience the environmental improvements associated with the EKC, as they are better equipped to implement and enforce environmental regulations. In contrast, weak institutions can delay or prevent the realization of the EKC turning point, as industries in these countries may continue to exploit natural resources and pollute the environment with minimal oversight (Wang & Wang, 2022). More recently, the dynamic relationship between income growth and environmental degradation has been examined in the context of global climate change. Recent studies argue that the EKC hypothesis must be reconsidered, considering rising global emissions and the need for sustainable development pathways. As countries grapple with the challenges of climate change, many scholars have called for the EKC framework to be expanded to incorporate global environmental challenges such as carbon neutrality and energy transitions. For instance, Zhang et al. (2020) emphasize that the EKC should not be viewed as an inevitable outcome of economic growth but rather as a goal that requires deliberate policy interventions and technological advancements.

FDI and CO2 Emissions

FDI is critical for economic growth, particularly in developing economies (Imam and Ahmad, 2022). However, the environmental implications of FDI remain contentious, with varying impacts depending on the nature of the investment and the institutional context of the host country. FDI can bring positive environmental outcomes by introducing advanced technologies, enhancing production efficiencies, reducing pollution, and contributing to more sustainable development (Zakaria & Bibi, 2019; Doytch and Uctum, 2011). This effect is particularly evident in sectors where clean technology transfers are facilitated, leading to lower energy consumption and carbon emissions.

However, in many cases, especially in countries with weak environmental regulations, FDI has been shown to exacerbate environmental degradation. In resource-rich developing nations, FDI is often concentrated in polluting industries such as mining, oil extraction, and heavy manufacturing, where the lack of stringent environmental policies allows for higher CO2 emissions (Seker et al., 2015; Cole and Elliott, 2003). The "pollution haven" hypothesis suggests that multinational corporations are incentivized to shift their most polluting operations to countries with lax environmental standards, increasing environmental harm in these host nations (Zhao and Zhang, 2021).

Recent studies underscore the critical role of institutional quality in moderating the environmental impact of FDI. Nguyen and Ha (2021) argue that in countries with strong

governance frameworks and effective environmental regulations, FDI is more likely to be directed toward sectors that promote sustainable development. In contrast, in nations where institutional quality is weak, FDI tends to flow into more environmentally harmful industries, exacerbating CO2 emissions. Blanton and Blanton (2015) further show that robust institutions can encourage foreign investors to adopt cleaner technologies and adhere to higher environmental standards. In contrast, weak institutions create opportunities for firms to exploit regulatory gaps and engage in unsustainable practices.

More recent research has also highlighted the differential impacts of FDI on sectoral composition. For example, Adedoyin et al. (2020) find that FDI in the renewable energy sector can significantly reduce CO2 emissions, especially in countries with favorable investment climates. This suggests that the sectoral distribution of FDI and the strength of institutional frameworks play a crucial role in determining its environmental impact.

Renewable Energy Consumption (REC) and CO2 Emissions

REC has emerged as a critical pathway for mitigating CO2 emissions, particularly in the context of rising global environmental concerns. As economies grow, the demand for energy surges, and without a shift towards renewable sources, CO2 emissions continue to escalate. Fossil fuels such as coal, oil, and natural gas are the primary contributors to greenhouse gas emissions, while renewable energy sources—including solar, wind, hydro, and biomass—offer a cleaner and more sustainable alternative. Numerous studies have demonstrated the potential of REC to reduce carbon emissions and promote sustainable economic development significantly (Acheampong et al., 2019; Al-Mulali et al., 2021).

The relationship between REC and CO2 emissions is well-established in the literature. Early studies, such as those by Apergis and Payne (2010), confirmed that countries with higher shares of REC in their energy mix tend to have lower CO2 emissions. This finding has been corroborated by more recent research, emphasizing the growing importance of renewable energy adoption in developed and developing economies. Alvarado et al. (2019) found that Latin American countries that invested in renewable energy projects saw significant reductions in carbon emissions, particularly in countries where institutional frameworks supported renewable energy development.

Recent empirical studies have further emphasized the critical role of REC in achieving carbon neutrality. For instance, Acheampong (2018) explored the causal relationship between economic growth, REC, and CO2 emissions in Sub-Saharan Africa and found that increasing REC led to significant carbon emissions reductions while supporting economic growth. Similarly, Mehmood (2021) analyzed the impact of renewable energy on CO2 emissions in the BRICS countries (Brazil, Russia, India, China, and South Africa), demonstrating that REC plays a crucial role in reducing environmental degradation in these emerging economies. The study concluded that investing in renewable energy infrastructure could benefit economic development and environmental sustainability.

However, transitioning from fossil fuels to renewable energy faces significant challenges, particularly in developing countries. Institutional barriers, including weak governance, lack of financial incentives, and inadequate infrastructure, hinder the widespread adoption of renewable energy (Ozturk & Acaravci, 2010). Acheampong et al. (2019) highlighted that Sub-Saharan Africa's reliance on fossil fuels is perpetuated by poor governance and the lack of a supportive institutional environment for renewable energy development. Without strong institutions that enforce energy transition policies and promote clean energy investments,

countries remain reliant on carbon-intensive energy sources, thus exacerbating environmental degradation (Shahbaz et al., 2020).

Institutional quality is vital in determining the success of renewable energy adoption and its ability to reduce CO2 emissions. Studies show that countries with robust institutional frameworks—characterized by effective governance, regulatory enforcement, and anti-corruption measures—are better positioned to transition to renewable energy and achieve significant reductions in carbon emissions (Omri and Saidi, 2022; Bilgili et al., 2020). The presence of strong institutions facilitates investments in renewable energy infrastructure, provides the necessary regulatory support for clean energy projects, and ensures compliance with environmental standards (Wang et al., 2022). In contrast, weak institutions fail to promote renewable energy effectively, leaving many developing nations dependent on fossil fuels and vulnerable to the adverse environmental impacts of climate change.

Moreover, the economic implications of REC are increasingly being recognized as part of broader strategies for achieving sustainable development. Renewable energy sources reduce environmental degradation and contribute to energy security, economic resilience, and job creation. For example, Saidi et al. (2018) argue that REC offers a sustainable development path for developing countries, allowing them to meet growing energy demands while minimizing their environmental footprint. The study found that countries investing in renewable energy infrastructure experienced long-term benefits in reducing carbon emissions, economic diversification, and improved public health outcomes.

Institutional Quality and CO2 Emissions

The influence of institutional quality on environmental outcomes has gained increasing attention in recent years. Strong institutions, characterized by robust governance structures, the rule of law, regulatory quality, and accountability mechanisms, are crucial in mitigating environmental degradation. Effective institutions ensure that environmental policies are designed and enforced, which can significantly reduce CO2 emissions (Acemoglu et al., 2014; Ali et al., 2019). Moreover, nations with high institutional quality tend to attract more environmentally responsible investments, as investors are required to comply with stringent environmental regulations (Gani, 2012). Recent empirical research has consistently shown that countries with stronger institutions experience better environmental outcomes. For example, Bilgili et al. (2020) found that governance quality is critical in reducing CO2 emissions by ensuring that environmental regulations are enforced and investments in green technologies are encouraged. Similarly, Omri and Saidi (2022) argue that institutional quality is essential for achieving long-term environmental sustainability, particularly in developing countries where governance weaknesses often undermine efforts to reduce emissions.

Institutional quality's role in addressing climate change challenges is also becoming more prominent. Liu et al. (2020) suggest that improving governance effectiveness and regulatory frameworks can enhance the implementation of climate change mitigation policies, leading to significant reductions in carbon emissions. Enforcing environmental laws and anti-corruption measures ensures that industries adhere to environmental standards, reducing the potential for environmental degradation (Kolstad & Wiig, 2011). In contrast, weak institutions are associated with higher levels of pollution, as industries in such countries are often able to bypass environmental regulations and engage in environmentally harmful activities. Ali et al. (2019) highlight that corruption and lack of accountability in countries with poor governance allow for unsustainable practices, leading to increased CO2 emissions and

environmental degradation. This creates a vicious cycle where environmental policies remain ineffective, worsening pollution levels.

Energy Consumption and CO2 Emissions

Energy consumption is widely recognized as a major driver of CO2 emissions, particularly in developing countries that depend heavily on fossil fuels. Non-renewable energy sources, such as coal, oil, and natural gas, dominate the energy mix in these countries, leading to significant increases in carbon emissions (Sadorsky, 2011). Studies consistently show a positive relationship between energy consumption and environmental degradation, as burning fossil fuels is directly linked to rising levels of CO2 (Apergis and Payne, 2009). More recent literature emphasizes the importance of transitioning to renewable energy to mitigate the environmental impact of energy consumption. REC, including wind, solar, and hydropower, is considered a cleaner alternative to support economic growth while reducing carbon emissions (Al-Mulali and Binti Che Sab, 2012). Research by Acheampong et al. (2019) demonstrates that countries with higher shares of REC experience lower CO2 emissions, underscoring the potential of renewable energy to combat climate change.

However, transitioning to renewable energy is often hindered by institutional barriers, particularly in developing countries. Ozturk and Acaravci (2010) argue that weak governance, inadequate policy incentives, and lack of infrastructure are major obstacles to the widespread adoption of renewable energy. For instance, Acheampong (2018) found that institutional weaknesses in Sub-Saharan Africa have delayed the region's transition to renewable energy, perpetuating reliance on fossil fuels and exacerbating environmental degradation. The role of institutional quality in facilitating the transition to renewable energy is increasingly recognized in the literature. Saidi et al. (2018) emphasize that strong institutions are necessary to promote renewable energy investments and ensure the successful implementation of energy reforms. Similarly, Alvarado et al. (2018) found that countries with better governance structures are more likely to attract investments in renewable energy projects, reducing CO2 emissions.

Gaps in the Existing Literature

Despite extensive research on the EKC, FDI, REC, and institutional quality, significant gaps remain, particularly in developing economies. Many studies rely on small, unbalanced panel datasets and yield mixed results, especially regarding the EKC's applicability in countries with weak governance and reliance on fossil fuels. The environmental impacts of FDI and REC are also underexplored, particularly in terms of the moderating role of institutional quality. Much of the research also focuses on short-term effects, overlooking long-term dynamics crucial for sustainability. Methodological limitations, such as failure to address endogeneity and cross-sectional dependence, further limit the robustness of previous findings. This study addresses these gaps by utilizing a balanced panel dataset, incorporating institutional quality, and employing advanced econometric techniques, including the GMM estimator and Driscoll-Kraay standard errors, to provide more comprehensive insights into sustainable development in developing countries.

Methodology and Data Collection

Model Specification and Data Collection

In this paper, we investigate the Environmental Kuznets Curve (EKC) hypothesis by utilizing a quadratic model like established frameworks (e.g., Bilgili et al., 2016). Our model is adapted

to evaluate the relationship between Income, IQ, FDI, and environmental degradation in 87 developing economies from 2000 to 2019. The core structure of the EKC suggests that pollution rises with income but eventually decreases as income surpasses a critical threshold, resulting in an inverted U-shaped curve. The general form of our model is as follows:

$$CO_2 = f(Y, Y,^2\ X) \qquad (1)$$

$$CO_2 = f(Y, Y,^2\ FDI, REC, EC) \qquad (2)$$

Where CO_2 denotes carbon dioxide emissions, Y represents the income proxy of GDP per capita, and Y^2 is the squared term of GDP per capita to capture the non-linear relationship. X includes additional explanatory variables such as FDI, EC, and REC. To incorporate these, the model is expanded as:

$$CO_{2it} = \beta_0 + \beta_1 LnY_{it} + \beta_2 LnY_{it}^2 + \beta_3 FDI_{it} + \beta_4 REC_{it} + \beta_5 EC_{it} + \mu_{it} \qquad (3)$$

In equation (3), the subscripts i and t denote country and time, respectively. β_0 is the intercept, $\beta_1$to β_5 are the coefficients of the variables, and μ_{it} is the error term. The variables are expected to interact in a way that validates the EKC hypothesis with $\beta_1 LnY_{it} + \beta_2 LnY_{it}^2$ initially contributing to rising emissions and Y^2 reducing emissions at higher income levels (H1).

IQ is introduced into the model to examine its moderating effect on environmental degradation, drawing from contemporary research on governance and environmental outcomes (e.g., Ali et al., 2019). Institutional quality metrics such as government effectiveness (GE) and the rule of law (RL) are hypothesized to alleviate environmental damage by enforcing regulations and promoting cleaner technologies. The enhanced model becomes:

$$CO_{2it} = \beta_0 + \beta_1 LnY_{it} + \beta_2 IQ_{it} + \beta_3 IQ \times \mathrm{Y}_{it} + \beta_4 FDI_{it} + \beta_5 REC_{it} + \beta_6 EC_{it} + \mu_{it} \qquad (6)$$

The interaction term $IQ \times \mathrm{Y}_{it}$ in equation (6) for how institutional quality influences the relationship between income and CO2 emissions. Higher institutional quality is expected to mitigate environmental degradation (H2), as better governance frameworks lead to stricter enforcement of environmental policies.

The study utilizes a balanced panel dataset covering 87 developing countries from 2000 to 2019. The data sources are reputable international organizations that ensure reliability and comparability. The dependent variable, CO2 emissions, is measured in metric tons per capita and sourced from the World Bank's World Development Indicators (WDI). Institutional Quality (IQ) is represented by government effectiveness (GE) and the rule of law (RL) indices from the World Governance Indicators (WGI), which rate governance quality on a scale from approximately -2.5 (weak governance) to 2.5 (strong governance). Income is the proxy of GDP per capita, which is measured in constant 2010 US dollars to control for inflation. This data is obtained from the World Bank. Foreign Direct Investment (FDI) is a net inflow of FDI as a percentage of GDP sourced from the World Bank, reflecting the role of foreign capital in economic and environmental outcomes. Renewable Energy Consumption (REC) is expressed as a percentage of total final energy consumption and reflects the share of energy sourced from renewables. Data is gathered from the World Bank. Energy consumption is measured in kilowatt-hours per capita, capturing the total energy use in each country. The data is sourced from the World Development Indicators.

To examine the impact of IQ, FDI, REC, and EC on environmental degradation, we apply the Generalized Method of Moments (GMM) estimator. The GMM is widely recognized for its ability to address key econometric challenges in panel data estimation, such as autocorrelation, heteroscedasticity, and endogeneity while improving the robustness of the

estimates. This technique is particularly suited for dynamic models where lagged variables may influence current outcomes, as is the case in our model examining CO2 emissions. Two prominent GMM approaches have emerged in the literature: the difference GMM, introduced by Arellano and Bond (1991), and the system GMM, developed by Arellano and Bover (1995) and further enhanced by Blundell and Bond (1998). While the DIF-GMM estimator has been employed in various contexts, it exhibits limitations, particularly when the dependent variable demonstrates strong persistence over time or when the panel data show a small period. In such cases, the transformed lagged levels are insufficient instruments for the differenced variables, leading to potentially biased estimates (Roodman, 2009).

Given the structure of the dataset, which comprises a relatively short period and high persistence in the independent variables, we implement the two-step SYS-GMM estimator. This approach allows us to estimate both short-run and long-run effects while mitigating the dynamic panel bias inherent in DIF-GMM. The SYS-GMM technique incorporates both the differenced and level equations, providing more efficient and consistent estimates, particularly when the instruments are weak, as noted by Bond et al. (2001). The two-step estimator is particularly valuable when the sample size is small, as it corrects for potential downward biases in the standard errors using the Windmeijer (2005) correction, thereby enhancing the reliability of the findings.

The SYS-GMM estimator is ideally suited to our analysis, where the dependent variable—CO2 emissions—is influenced by a set of explanatory variables, including GDP per capita, institutional quality, FDI inflows, renewable energy consumption, and energy consumption. Moreover, this method effectively addresses issues of reverse causality and endogeneity that may arise, for instance, when income influences environmental outcomes and vice versa. The two-step SYS-GMM model accounts for these dynamic interactions and provides robust results in small sample contexts (Baum et al., 2003). In order to ensure the validity of our instruments, we employ the Hansen test for over-identifying restrictions, which evaluates the appropriateness of the instruments used in the GMM estimation. Additionally, the Arellano-Bond test is conducted to check for the presence of second-order serial correlation in the residuals, further ensuring the consistency of the model.

Results and Discussions

Results

For this study, we employed the two-step system dynamic panel estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998). This estimator effectively accounts for potential endogeneity issues that often arise in panel data by utilizing lagged variables as instruments. Moreover, we introduced time dummies to control for time-specific effects and mitigate the influence of global shocks, as recommended by Roodman (2009a). To prevent instrument proliferation, we minimized the number of instruments used in the model, following the best practices outlined by Roodman (2009b).

Table 1 provides the estimation results for both the one-step and two-step dynamic panel estimators. In line with Windmeijer (2005), we focus on interpreting the results from the two-step system estimator, as it is more reliable for small sample sizes and addresses potential downward bias. Our empirical findings confirm the presence of the Environmental Kuznets Curve (EKC) hypothesis for the selected developing countries. Specifically, the coefficient for GDP per capita is positive, while the coefficient for the square of GDP per capita is negative across all models. This supports the inverted U-shaped relationship between income and CO2 emissions, indicating that pollution initially rises as income grows but declines after reaching

a certain threshold (Grossman & Krueger, 1995; Panayotou, 1993). Similar findings have been reported by other studies examining the EKC hypothesis in both developed and developing countries (Dinda, 2004; Stern, 2004), further validating our results.

In terms of FDI, the results show a positive and statistically significant relationship with CO2 emissions in most models, aligning with prior research suggesting that FDI can exacerbate environmental degradation in developing countries where institutional frameworks are weak (Cole and Elliott, 2003; Seker et al., 2015). This supports the notion that, in the absence of stringent environmental regulations, FDI may contribute to pollution, particularly when pollution-intensive industries relocate to countries with laxer standards (Nguyen and Ha, 2021). However, some studies have also highlighted the potential for FDI to mitigate carbon emissions when it brings advanced, clean technologies to host countries, though this often depends on the strength of local institutions (Tang and Tan, 2015; Zakaria and Bibi, 2019). REC, the coefficient is generally negative but not always statistically significant. This suggests that while renewable energy holds the potential to reduce CO2 emissions, its current role in mitigating pollution in developing countries remains limited. This finding aligns with studies by Apergis and Payne (2010) and Sadorsky (2009), which highlight that the adoption of renewable energy in developing countries is still in its early stages. The lack of infrastructure, policy incentives, and the continued dominance of non-renewable energy sources may explain the limited impact of renewable energy on reducing emissions at this stage (Al-Mulali and Binti Che Sab, 2012; Ozturk and Acaravci, 2010). EC demonstrates a positive and statistically significant relationship with CO2 emissions in all models. This confirms that higher levels of energy consumption, particularly from non-renewable sources such as fossil fuels, are a key driver of rising emissions in developing countries (Sadorsky, 2011; Shahbaz et al., 2013). This finding underscores the urgent need for these countries to transition to cleaner, renewable energy sources to mitigate the adverse environmental effects of growing energy demand (Apergis et al., 2010).

Table 1
Estimation Results for the EKC Hypothesis

Variables	One-step SYS-GMM	Two-step SYS-GMM
CO_{2it-1}	0.9350***	0.9180***
	(0.0480)	(0.0562)
Y_{it}	1.3421	1.8054***
	(0.9621)	(0.7514)
Y^2_{it}	-0.0860	-0.1053**
	(0.0543)	(0.0468)
FDI_{it}	0.0072**	0.0081**
	(0.0039)	(0.0042)
REC_{it}	-0.0015	-0.0021
	(0.0017)	(0.0020)
EC_{it}	0.0091**	0.0102**
	(0.0046)	(0.0043)
F-statistic	2456.31	2150.74
p-value	0.0000	0.0000
AR(1)	0.0028	0.0031
AR(2)	0.8420	0.8651
Hansen P-value	0.1141	0.1524
Observations	1,740	1,1740
Instruments	25	27
Time dummies	Yes	Yes

Notes: Robust standard errors are reported in parentheses. ***, **, and * denote

significance levels at 1%, 5%, and 10%, respectively. Data were collected for 87 developing countries over the period 2000–2019. Source: Author's calculations.

Diagnostic tests confirmed the robustness of our results. The Hansen test for over-identifying restrictions yielded non-significant p-values, indicating that the instruments used in the model are valid and not over-identified. Furthermore, the Arellano-Bond tests for serial correlation showed no evidence of second-order autocorrelation in the residuals, confirming the appropriateness of the model specification (Arellano & Bond, 1991).

Table 2 presents the results of model 1, which incorporates institutional quality measured by GE. The results reveal a strong negative relationship between GE and carbon emissions across all models, suggesting that improved governance structures significantly reduce environmental degradation in developing countries. This finding is consistent with studies showing that higher institutional quality enhances environmental performance by ensuring more effective enforcement of environmental policies and regulations (Ali et al., 2019; Acemoglu et al., 2014). Institutions that promote accountability, transparency, and robust law enforcement are more likely to curb pollution, aligning with our hypothesis that stronger institutions contribute to lower CO2 emissions.

FDI shows a positive and significant relationship with CO2 emissions, suggesting that, in many developing countries, FDI contributes to environmental degradation. This result supports the "pollution haven hypothesis," which posits that firms from developed nations often relocate pollution-intensive industries to countries with weaker environmental regulations (Cole & Elliott, 2003; Seker et al., 2015). The influx of foreign capital may prioritize economic gains over environmental sustainability, especially in countries lacking strong institutional

frameworks to enforce environmental standards. However, previous research also notes that FDI can mitigate environmental degradation if it brings advanced, clean technologies, as seen in nations with stronger governance (Tang & Tan, 2015; Zakaria & Bibi, 2019).

The coefficient for REC is also negative and statistically significant, reinforcing the argument that the increased use of renewable energy sources reduces CO2 emissions. This result aligns with the literature indicating that transitioning to cleaner energy sources, such as wind and solar, plays a crucial role in reducing environmental pollution, especially in developing economies where the reliance on non-renewable energy remains high (Apergis & Payne, 2010; Sadorsky, 2009). The adoption of renewable energy technologies is essential for countries seeking to meet their environmental targets while sustaining economic growth.

In model 2, EC is used as an additional variable. EC has a positive and statistically significant impact on carbon emissions, particularly in the second model, which includes energy consumption as a control variable. This result confirms the well-established link between energy consumption, particularly from fossil fuels, and rising CO2 emissions (Sadorsky, 2011; Shahbaz et al., 2013). As developing economies industrialize, their energy demands rise, contributing directly to environmental degradation unless a transition to renewable energy sources occurs. The result supports our hypothesis that higher energy consumption exacerbates pollution in the absence of cleaner energy alternatives.

Table 2
Estimation Results For Co2 Emissions in Developing Countries with and without Energy Consumption

Variables	Model 1	Model 2	Model 3	Model4
	(Without EC)	(With EC)	(Without EC)	(With EC)
CO_{2it}	0.8923***	0.8812***	0.2037**	0.2922***
	(0.0481)	(0.0515)	(0.0920)	(0.1156)
Y_{it}	0.2320**	0.3140***	0.0092*	0.0095**
	(0.0812)	(0.1214)	(0.0049)	(0.0051)
FDI_{it}	0.0081*	0.0084**	-0.0045**	-0.0050**
	(0.0039)	(0.0042)	(0.0017)	(0.0020)
REC_{it}	-0.0037**	-0.0039**	0.2037**	0.2922***
	(0.0018)	(0.0021)	(0.0920)	(0.1156)
GE_{it}	-0.5423***	-0.6134***		
	(0.2531)	(0.3112)		
$Y_{it} \times GE_{it}$	0.0641**	0.0722**		
	(0.0304)	(0.0385)		
RL_{it}			-0.3254*	-0.4121**
			(0.2123)	(0.2214)
$Y_{it} \times RL_{it}$			0.0367	0.0429
			(0.0278)	(0.0381)
EC_{it}		0.0114**		0.0118**
		(0.0047)		(0.0045)
Time dummies	Yes	Yes	Yes	Yes
F-statistic	1890.76	1545.29	1796.03	1632.42
p-value	0.0000	0.0000	0.000	0.000
AR(1)	0.0029	0.0030	0.0030	0.0021
AR(2)	0.8351	0.8442	0.624	0.763
Hansen (p-value)	0.196	0.143	0.125	0.162
Observations	1740	1740	1740	1740
Instruments	28	30	28	26

Notes: Robust standard errors are in parentheses. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively. The data set covers 115 developing countries from 2000 to 2019. Source: Author's calculations.

The diagnostic tests further validate our models. The Arellano-Bond test for autocorrelation shows no evidence of second-order serial correlation. In contrast, the Hansen test for instrument validity yields non-significant p-values, confirming that the instruments used in the models are appropriate. These diagnostic results indicate that the models are well-specified, and the estimated coefficients are reliable and consistent with the best practices in dynamic panel data estimation (Arellano & Bond, 1991; Windmeijer, 2005).

Models 3 and 4 illustrate the results from the dynamic panel model, with and without the inclusion of EC. The results reveal that RL exhibits a negative relationship with CO2 emissions in both models, suggesting that stronger institutional quality plays a significant role in reducing environmental degradation. This finding aligns with previous studies that highlight the importance of robust institutional frameworks in promoting environmental sustainability by enforcing regulations and curbing pollution (Acemoglu et al., 2014; Ali et al., 2019). However, the interaction between Y and RL, while positive, is not statistically significant,

indicating that income alone cannot mitigate environmental impacts without corresponding institutional reforms. This reflects the argument that income in developing countries may exacerbate pollution in the absence of strong institutions (Leitao, 2010). FDI is positively associated with CO2 emissions in both models, confirming that FDI contributes to environmental degradation in developing countries. This result supports the pollution haven hypothesis, which posits that FDI inflows often lead to higher pollution when countries with weaker environmental regulations attract industries with high emissions (Cole & Elliott, 2003; Seker et al., 2015). The results for REC consistently show a negative and significant impact on CO2 emissions, underscoring the role of renewable energy in reducing pollution.

In model 4, the inclusion of EC reveals a significant positive relationship with CO2 emissions, confirming that rising energy demand contributes to environmental degradation. This finding aligns with the literature that highlights how increasing energy consumption, particularly from fossil fuels, is a major driver of CO2 emissions in developing countries (Sadorsky, 2011; Shahbaz et al., 2013). As developing economies industrialize and grow, their energy requirements expand, often leading to higher levels of pollution unless cleaner energy sources are adopted.

To evaluate the long-run effects of IQ, FDI, REC, and EC on environmental degradation, we calculate the long-run coefficients based on significant short-run estimates, including the interaction between income Y and institutional quality (GE and RL).

$$\beta_{long-run} = \frac{\beta_{short-run}}{1-\delta}$$

Table 3

Long-Run Coefficient Estimates for CO2 Emissions

Variables	Model 5	Model 6	Model 7	Model 8
	(Without EC)	(With EC)	(Without EC)	(With EC)
$CO2_{it}$	7.6543**	7.3401**	8.2101**	8.3002*
	(3.4122)	(3.5198)	(4.1571)	(4.4915)
Y_{it}	1.8405***	2.6435***	1.7815***	2.6112***
	(0.3621)	(0.4971)	(0.4081)	(0.4830)
FDI_{it}	0.0625*	0.0705*	0.0783*	0.0852**
	(0.0044)	(0.0372)	(0.0422)	(0.0435)
REC_{it}	-0.0363***	-0.0470***	-0.0348***	-0.0450***
	(0.0075)	(0.0081)	(0.0076)	(0.0082)
GE_{it}	-4.2939*	-6.3286**		
	(2.3854)	(2.7101)		
$Y_{it} \times GE_{it}$	0.4739*	0.7072**		
	(0.2934)	(0.3298)		
RL_{it}			-2.3547*	-3.4244**
			(2.0653)	(2.0134)
$Y_{it} \times GE_{it}$			0.2230	0.3420
			(0.2591)	(0.2480)
EC_{it}		0.0787***		0.0794***
		(0.0193)		(0.0214)

Notes: ***, **, and * denote significance at 1%, 5%, and 10%, respectively. Source: Author's calculations.

Table 3 presents the long-run effects, with institutional quality measured through GE and RL. The results indicate that a 1% improvement in GE reduces CO2 emissions by approximately 6.32% in the model with EC. This finding supports the view that improving governance and institutional quality can effectively mitigate environmental degradation by ensuring better enforcement of environmental regulations (Acemoglu et al., 2014; Gani, 2012). However, the interaction between income and GE is positive but statistically insignificant, suggesting that income alone may not significantly reduce environmental degradation, even with stronger institutional quality. This is consistent with research indicating that income, in the absence of stringent environmental policies, can still lead to increased emissions (Dinda, 2004). The coefficient for REC in models 5 and 6 remains negative and significant, indicating that a 1% increase in renewable energy consumption reduces CO2 emissions by approximately 0.047%. This underscores the importance of transitioning to renewable energy sources in reducing environmental harm, a finding that has been widely supported in the literature (Apergis & Payne, 2010; Sadorsky, 2009). Meanwhile, both FDI and EC contribute to increased emissions, highlighting the need for stronger institutional controls and cleaner energy alternatives to curb the adverse environmental effects of industrialization and foreign investment (Seker et al., 2015).

In Model 6, RL is shown to have a significant negative impact on CO2 emissions, with a 1% improvement in RL leading to a reduction in emissions by approximately 3.42%. This further supports the argument that strong institutions are critical in mitigating environmental degradation (Kolstad & Wiig, 2011). However, similar to the GE model, the interaction between income and RL is positive but not statistically significant, indicating that income alone may not be sufficient to curb emissions, even in the presence of stronger institutional quality. This finding echoes studies suggesting that robust institutional frameworks are necessary for economic growth to be environmentally sustainable (Leitao, 2010).

In both models 6 and 7, FDI and EC remain positively associated with CO2 emissions, confirming the role of energy consumption and foreign investment in driving environmental degradation, particularly in developing countries (Shahbaz et al., 2013). REC, however, continues to show a significant negative impact, reinforcing its role in reducing emissions and promoting environmental sustainability.

Robustness Check

To verify the reliability of our findings, we employed Driscoll and Kraay standard errors for robustness checks. This method is highly effective in addressing potential issues such as cross-sectional dependence, heteroscedasticity, and serial correlation, which are common in panel data analysis (Driscoll & Kraay, 1998). By using this approach, we ensured that the results remained consistent and valid despite any underlying data irregularities.

The robustness checks confirmed that GE's negative impact on CO2 emissions is significant, supporting the notion that strong governance structures are crucial for reducing environmental degradation (Acemoglu et al., 2014; Gani, 2012). Specifically, a 1% increase in GE results in a 7.46% reduction in CO2 emissions, which is significant at the 1% level. This finding reinforces the argument that well-functioning institutions can enforce environmental regulations more effectively and promote sustainable development (Ali et al., 2019; Kolstad & Wiig, 2011). Moreover, REC also showed a significant negative impact, with a 1% increase in REC leading to a 0.05% reduction in CO2 emissions. This result highlights the potential of renewable energy to mitigate pollution in developing countries, consistent with previous studies that emphasize the environmental benefits of transitioning to cleaner energy sources

(Sadorsky, 2009; Apergis & Payne, 2010). The growing adoption of renewable energy technologies is seen as a vital tool for reducing emissions and achieving long-term environmental sustainability (Al-Mulali & Binti Che Sab, 2012).

Furthermore, the interaction term between income Y and GE is positive and statistically significant. This suggests that while institutional quality helps to reduce emissions, income alone cannot effectively address environmental challenges without the presence of strong governance frameworks (Leitao, 2010). The combination of effective institutions and responsible economic policies is necessary to ensure that growth does not come at the expense of environmental degradation. FDI, although not consistently significant, continues to show a positive relationship with emissions, and REC exhibits a negative significant effect on CO2. EC, when included in model 2(a), demonstrates a significant positive impact on CO2 emissions, confirming that rising energy demand in developing countries contributes to increased pollution.

Table 6
Robustness Check of CO2 Emissions with Driscoll-Kraay Standard Errors

Variables	Model 1 (a)	Model 2 (a)
Y_{it}	2.1032***	2.7924***
	(0.0910)	(0.0948)
FDI_{it}	0.0065	0.0132**
	(0.0064)	(0.0067)
REC_{it}	-0.0407***	-0.0493***
	(0.0013)	(0.0015)
GE_{it}	-5.2735***	-7.4649***
	(0.4424)	(0.5333)
$Y_{it} \times GE_{it}$	0.5408***	0.8077***
	(0.0555)	(0.0648)
EC_{it}		0.0897***
		(0.0197)
Constant	12.5670***	15.7635***
	(0.7732)	(0.7271)
F-statistic	3830.82	11,505.22
Prob > F	0.0000	0.0000
R-Squared	0.4224	0.4518
Max: Lag	2	2
Root MSE	3.1287	3.0751
Observations	1,740	1,740
Groups	87	87

Notes: ***, **, and * denote significance at 1%, 5%, and 10%, respectively. Source: Author's calculations.

Discussion

The findings of this study provide robust evidence for the Environmental Kuznets Curve (EKC) hypothesis and offer significant insights into how IQ, FDI, REC, and overall EC shape environmental outcomes in developing countries. The validation of the EKC hypothesis, which posits an inverted U-shaped relationship between income and environmental degradation, is consistent with the broader literature. As indicated by the positive coefficient for income and the negative coefficient for the squared term of income, pollution tends to rise in the early stages of economic development but eventually declines as income levels increase. This confirms previous studies, such as Grossman and Krueger (1995) and Panayotou (1993), which argue that economic growth can initially lead to higher emissions before more sustainable practices are adopted as income and institutional capacities improve.

IQ emerges as a critical factor in mitigating environmental degradation, with both GE and the RL showing significant negative relationships with carbon emissions. These results echo the work of Acemoglu et al. (2014) and Gani (2012), which highlight the importance of strong governance in enforcing environmental regulations and promoting sustainable practices. The positive interaction terms between income and institutional quality suggest that institutional frameworks not only help mitigate emissions but also enhance the ability of countries to manage the environmental impacts of economic development. This reinforces the notion that governance structures need to be strengthened to address the adverse effects of economic expansion. However, the insignificance of some interaction terms indicates that income alone cannot solve environmental issues without concurrent improvements in institutional quality, aligning with findings by Leitao (2010).

FDI was found to contribute to environmental degradation, particularly in developing countries with weak regulatory frameworks, confirming the "pollution haven hypothesis" (Cole & Elliott, 2003). This result supports the argument that countries with lax environmental regulations attract industries that generate high emissions, as seen in the work of Seker et al. (2015). The positive relationship between FDI and CO2 emissions underscores the need for stronger institutional oversight to ensure that FDI inflows contribute to sustainable development. However, this study also recognizes the potential for FDI to reduce emissions when accompanied by advanced, cleaner technologies, as suggested by Tang and Tan (2015) and Zakaria and Bibi (2019). Thus, the dual role of FDI in either exacerbating or mitigating environmental degradation depends heavily on the host country's institutional quality. The results for REC suggest that while REC holds promise for reducing emissions, its adoption remains limited in developing countries. The negative and significant relationship between REC and emissions supports the growing body of literature that emphasizes the environmental benefits of renewable energy, such as the work by Apergis and Payne (2010) and Sadorsky (2009). However, barriers such as inadequate infrastructure, insufficient policy support, and the continued dominance of non-renewable energy sources constrain the full potential of renewable energy in these regions (Al-Mulali & Binti Che Sab, 2012). As such, greater efforts are needed to accelerate the transition to cleaner energy sources and to integrate renewable technologies into the energy mix of developing economies.

EC, particularly from non-renewable sources, continues to be a significant driver of CO2 emissions in developing economies. The positive and significant relationship between EC and emissions highlights the ongoing reliance on fossil fuels, as supported by Sadorsky (2011) and Shahbaz et al. (2013). As these countries pursue industrialization and economic growth, their energy demands rise, contributing directly to increased pollution. This finding underscores the urgency for developing countries to transition to cleaner energy sources, a challenge that requires both policy incentives and significant investment in renewable energy infrastructure. Finally, the robustness checks using Driscoll and Kraay standard errors confirm the reliability of these findings. The continued significance of institutional quality in reducing CO2 emissions, along with the consistent results for REC and EC, underscores the importance of robust governance structures and energy transitions in addressing environmental challenges. Stronger institutional frameworks not only help enforce environmental regulations but also play a critical role in moderating the impact of income and FDI on environmental degradation. For developing countries seeking to balance economic expansion with environmental sustainability, the findings of this study suggest that institutional reforms, combined with increased investment in renewable energy, are key to achieving long-term sustainable development.

Conclusion

This study provides valuable insights into the role of institutional quality in shaping the impact of FDI and energy consumption on environmental degradation in developing economies. By examining the Environmental Kuznets Curve (EKC) hypothesis and integrating key variables such as institutional quality, FDI, REC, and EC, this research highlights the complex interactions between income and environmental outcomes. The validation of the EKC hypothesis confirms that while income initially exacerbates pollution, emissions tend to decline once a certain income threshold is reached, in line with previous studies such as Grossman and Krueger (1995) and Panayotou (1993). This finding suggests that as developing countries grow economically, their capacity to adopt cleaner technologies and implement more effective environmental regulations improves, contributing to reduced emissions. IQ emerged as a critical factor in mitigating environmental degradation. Strong institutions, characterized by government effectiveness and robust rule of law, play a crucial role in enforcing environmental regulations and promoting sustainable practices.

Countries with better governance are more capable of managing the environmental impacts of income, FDI, and energy consumption. This underscores the importance of institutional reforms in addressing the environmental challenges faced by developing countries. FDI was found to have a dual impact on environmental degradation. In the absence of strong institutional frameworks, FDI can exacerbate pollution, supporting the "pollution haven hypothesis." However, FDI also has the potential to mitigate environmental harm when it brings advanced, clean technologies to host countries, a process that is contingent upon the strength of local institutions. Therefore, improving institutional quality is key to ensuring that FDI contributes to environmental sustainability in developing economies. EC, particularly from non-renewable sources, remains a significant driver of carbon emissions in developing countries. The positive relationship between EC and emissions highlights the need for a transition to cleaner energy sources. While renewable energy holds promise for reducing emissions, its adoption in developing economies is still limited, requiring substantial investment and policy support to realize its full potential.

The robustness of the study's results was confirmed through diagnostic tests and robustness checks, further reinforcing the critical role of institutional quality and energy transitions in addressing environmental degradation. For policymakers in developing countries, the findings of this study suggest that strengthening governance frameworks, attracting environmentally responsible FDI, and accelerating the shift towards renewable energy are essential steps for achieving sustainable development. In conclusion, this research emphasizes the importance of institutional quality in shaping environmental outcomes. It provides evidence that developing countries can achieve both income and environmental sustainability by implementing institutional reforms, encouraging clean technologies, and investing in renewable energy. By addressing these key areas, developing economies can progress toward meeting their Sustainable Development Goals (SDGs) and promoting long-term environmental sustainability.

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