IJEEP
INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY
EJ EconJournals ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2026, 16(2), 28-46.

Revisiting the Finance-Environment Nexus: The Joint Role of Remittances and FDI in Sustainable Development

Ayesha Serfraz[1], Md Qamruzzaman[2]*

[1]Institute of Administrative Sciences, University of the Punjab, Pakistan, [2]United International University, Dhaka, Bangladesh.
*Email: qamruzzaman@bus.uiu.ac.bd

Received: 01 September 2025 **Accepted:** 26 December 2025 **DOI:** https://doi.org/10.32479/ijeep.22216

ABSTRACT

This study examines the influence of remittances, imports, household consumption, renewable energy consumption, financial development, globalization, and institutional quality on environmental sustainability in major remittance-receiving economies. Environmental degradation is assessed through CO_2 emissions and the ecological footprint, allowing for a comprehensive evaluation of both emission intensity and ecological pressures. Utilizing annual data and advanced panel econometric methods, this analysis addresses cross-sectional dependence, slope heterogeneity, persistence, and endogeneity. The empirical framework integrates cross-sectionally augmented ARDL (CS-ARDL) for baseline long- and short-run dynamics, robustness checks using common correlated effects mean group (CCEMG) and augmented mean group (AMG), dynamic generalized method of moments (GMM) estimators, and asymmetric nonlinear ARDL specifications. Additionally, Panel quantile regression with method of moments (PQR-MM) was employed to capture heterogeneous effects across the distribution of environmental outcomes. The results indicate that remittances contribute to environmental improvements, although the magnitude varies between positive and negative shocks, confirming asymmetric effects. Renewable energy consumption consistently mitigates environmental degradation across specifications. Conversely, imports, household consumption, financial development, and globalization exacerbate ecological pressures, whereas institutional quality plays a crucial moderating role in reducing adverse environmental impacts. The quantile estimates reveal the stronger effects of remittances, renewable energy, and governance at higher levels of environmental stress, emphasising the importance of policy targeting in heavily affected economies. These findings underscore the interplay between financial flow, governance, and energy use in global sustainability. This study contributes to the literature on globalization by illustrating how remittances and institutional frameworks can transform global integration and financial expansion into opportunities for ecological resilience, aligned with international climate and development agendas.

Keywords: Remittances, Globalization, Institutional Quality, Renewable Energy, Financial Development, Environmental Sustainability; CO_2 Emissions, Ecological Footprint
JEL Classifications: F21; F24; Q53; Q56

1. INTRODUCTION

Remittances to developing countries have increased significantly in the last three decades, with the majority going to developing countries. In 2022, total remittances reached $831 billion, with over 79% going to developing countries (Kshetri, 2023). Remittances are a stable source of foreign funds and play a crucial role in economic development, particularly in achieving sustainable development goals (SDGs). They have direct links with goals 13 and 14 related to the environment. However, research suggests that remittances can have adverse environmental effects, such as promoting energy-intensive production and consumption, increasing CO_2 emissions, and ecological degradation (Yang et al., 2021). Multiple studies have discovered that remittances hurt the environment in regions such as South Asia, China, Ghana, and Pakistan. The remittance increase has been linked to higher CO_2 emissions and the allocation of funds towards high-polluting goods, which can harm the ecological state (Li et al., 2022; Liu et al., 2022; Rani et al., 2023). Remittances also influence the environment through the demand for goods and services, leading to new businesses that contribute to carbon emissions and degrade environmental quality (Ahmad et al., 2019). If remittances continue to harm the environment, it will have significant consequences for sustainable development goals (SDGs) (Akanle et al., 2022). Remittances have been shown to positively affect underprivileged households, such as improving food security, reducing hunger and poverty, and supporting education, health, and financial inclusion. They also contribute to financial development, investment, and economic growth by providing capital to small businesses and helping to finance imports and external debt (Sobiech, 2019). However, it is essential to note that remittances have also been associated with environmental degradation. A large inflow of remittances triggers the consumption and production of traditional energy-intensive goods, leading to environmental degradation by increasing energy consumption (Rani et al., 2023). Studies have found conflicting findings on the relationship between remittances and the environment. While some studies suggest that remittances hurt the environment due to increased financial and industrial development and higher energy consumption, other studies suggest a positive impact by promoting technological innovations and encouraging sustainable development.

The impact of remittances on the environment is a subject of ongoing discussion and research. Some studies suggest that remittances hurt the environment, while others propose a more complex relationship. Tebourbi et al. (2023) found no direct connection between remittances and the environment, and better institutional quality was found to mitigate any negative impact. Other studies by Rahman et al. (2021), Elbatanony et al. (2021), and Islam (2022) have found that the relationship between remittances and environmental quality is not straightforward. Initially, remittances may lead to environmental degradation by increasing the consumption and production of traditional goods. However, as income levels rise, remittances have been found to promote environmental quality by encouraging green production and consumption. The choice to focus on South Asian countries in this research is essential for a few reasons. Firstly, these countries receive a significant amount of remittances, more than what they receive in foreign direct investment and foreign aid (Das and Sethi, 2020). Secondly, this region is a significant contributor to environmental pollution, particularly in terms of CO_2 emissions (Mughal et al., 2022). Lastly, previous studies on South Asian countries have produced conflicting results, indicating the need for further investigation.

The research on the relationship between remittances and environmental sustainability is motivated by a growing recognition of the intricate interplay between economic activities, migration patterns, and environmental well-being. Remittances play a vital role in supporting recipient households, influencing their spending habits and trade patterns. Developing a thorough understanding of the dynamics of this relationship is crucial for creating and implementing policies that achieve a harmonious balance between economic development and environmental conservation (Dash et al., 2024; Liu et al., 2023; Williams, 2021). This study aims to offer valuable insights into the correlation between remittances and environmental challenges. The goal is to analyze how consumption and trade behaviours, impacted by remittances, can have an impact on the environment. The study's importance lies in its capacity to offer valuable insights for policy decisions, particularly in the field of remittances. Through a comprehensive analysis of the benefits and possible environmental consequences, this study aims to provide valuable insights for policymakers to make informed decisions. By conducting a comprehensive analysis of the intricate links between remittances, consumption, and trade, this study aims to provide valuable perspectives on methods to encourage sustainable development and reduce the environmental consequences of economic activities fueled by remittances. Furthermore, the findings could offer valuable insights for governments, international organisations, and local communities to create effective strategies that utilise remittances for the dual objectives of economic growth and environmental conservation. This approach would encourage a comprehensive and enduring approach to development. This study offers valuable insights into the ongoing discussion on sustainable development and provides practical guidance for policymakers grappling with the challenge of harmonising economic growth and environmental protection.

Global environmental sustainability has become a defining challenge for globalisation. Rising carbon emissions and growing ecological footprints reflect the consequences of financial flow, household consumption, trade, and integration into global markets. This issue is particularly relevant in remittance-dependent economies. Remittances represent a critical source of income and foreign exchange, often exceeding foreign direct investment. However, their environmental implications remain underexplored, with existing studies focusing primarily on economic growth, poverty, and financial stability. The significance of this study lies in its examination of how remittances, globalization, institutional quality, and the related financial and consumption dynamics interact to influence environmental outcomes. By incorporating both CO_2 emissions and ecological footprint as indicators, the analysis captures emission intensity as well as the broader resource pressures generated by economic activity. This dual measure allows for a comprehensive assessment of environmental sustainability in the context of global financial flow.

The central research questions were as follows.

RQ1. How do remittances, imports, household consumption, renewable energy, financial development, globalization, and institutional quality affect the environmental degradation in remittance-receiving economies?

RQ2. Do these relationships differ in the short and long run?

RQ3. Are the effects of remittances, globalization, and institutions asymmetric depending on positive or negative shocks?

RQ4. Do the impacts vary across the distribution of environmental degradation, as captured by different quantiles of CO_2 emissions and the ecological footprint?

From these questions, the following hypotheses were developed.

H_1: Remittances reduce environmental degradation in the long run but may increase it in the short run through scale effects.

H_2: Imports and household consumption intensify environmental pressure, but their nonlinear effects allow for eventual mitigation via composition changes.
H_3: Renewable energy consistently lowers CO_2 emissions and ecological footprint.
H_4: Financial development increases environmental degradation, unless aligned with green finance.
H_5: Globalization has mixed effects, intensifying degradation through trade scale effects but reducing it when technology transfer dominates.
H_6: Institutional quality moderates adverse environmental impacts and reduces degradation across both indicators.

This research makes significant contributions to the discourse on globalization, remittances, and sustainability. Initially, it expanded the empirical framework of environmental studies by concentrating on economies that receive remittances, a category often overlooked in comparative environmental research. Most existing analyses focus on developed nations or broad cross-country datasets, frequently ignoring the unique structural attributes of economies that depend on foreign financial inflows. Furthermore, this study introduces a dual approach to measuring environmental degradation, utilising both CO_2 emissions and ecological footprint. While CO_2 emissions highlight the atmospheric impact of economic activities, the ecological footprint provides a broader perspective on the demand placed on ecosystems, relative to their biocapacity. This dual measurement offers a more comprehensive understanding of how financial flows and global integration affect sustainability, beyond mere carbon intensity. Additionally, this study enhances methodological precision by employing advanced panel econometric techniques that address cross-sectional dependence, slope heterogeneity, and dynamic persistence. The integration of CS-ARDL, CCEMG, AMG, and System-GMM ensures a robust estimation of both short-term and long-term effects. The use of asymmetric NARDL decompositions captures nonlinear dynamics, whereas quantile-based methods (PQR-MM) reveal distributional heterogeneity across economies with varying emission levels. Moreover, this study emphasises the importance of institutional quality in determining environmental outcomes. Although globalization and financial development have been extensively studied, the role of governance as a moderating factor in directing financial flows and trade towards environmentally sustainable outcomes has received limited attention. By incorporating institutional indicators from the Worldwide Governance Indicators dataset, this study demonstrated the influence of governance capacity on ecological resilience. Finally, the findings contribute to policy-oriented literature by providing insights into how remittance flows can be harnessed to support clean energy adoption and sustainable consumption practices. This aligns with the study of global sustainability agendas and sustainable development goals (SDGs), particularly SDG 7 (clean energy), SDG 13 (climate action), and SDG 16 (institutional effectiveness).

The structure of the article is as follows: Section II deals with a literature survey and exploration of the literature gap. The data, variables and methodology of the study are displayed in Section III, and model estimation and interpretation are available in Section IV. Section IV reported the discussion and conclusion, and policy suggestions available in Section VI, respectively.

2. LITERATURE REVIEW

2.1. Nexus between Remittances and the Environment

Remittances contribute to environmental degradation through increased CO_2 emissions and the production of energy-intensive products, as observed in South Asia, China, Ghana, Nigeria and Pakistan (Zhao and Qamruzzaman, 2022), (Akinlo, 2022). Remittances contribute to higher CO_2 emissions and support the purchase of environmentally harmful products, negatively impacting ecological quality. Indirectly, remittances boost financial development and support business growth by increasing funds for new ventures and expanding existing industries—higher remittances result in more savings and consumption. As remittances increase, higher returns from human capital investments and increased productivity, benefiting savings, consumption, and children's education, also increase (Benhamou and Cassin, 2021). Remittances contribute to higher CO_2 emissions and support the purchase of environmentally harmful products, negatively impacting ecological quality (Musah, 2023). Remittances, by being directly received by people in need and not by governments as intermediaries, would serve more households' interests and be more effective in favouring economic development than foreign aid (Baldé, 2011).

These studies investigated the relationship between remittances and CO_2 emissions in different countries, including Pakistan, Ghana, India, and Bangladesh. Ahmad et al. (2022) found that remittances increased emissions in Pakistan and data periods (1976Q1-2020Q4) for Pakistan, which was consistent with the conclusions drawn by Chishti et al. (2023), Zaman et al. (2023) using different methodologies and data. Li et al. (2022) also found a detrimental effect of remittances on ecological quality in Ghana. Similar adverse impacts of remittances on the environment were observed in studies focusing on Ghana, indicating a detrimental effect on ecological quality by elevating CO_2 emissions. Studies focusing on India Neog and Yadava (2020) and Bangladesh Kibria (2022) echoed these adverse impacts of remittances. Nevertheless, a few studies (Qamruzzaman et al., 2023; Serfraz et al., 2023; Tan et al., 2023) did find favourable effects of remittances on environmental quality. Kibria et al. (2021) conducted a study in South Asia and found that energy consumption harmed the environment, while the impact of financial development was mixed. In another study, Kibria (2023) focused on the relationship between economic complexity and the ecological footprint in Bangladesh. Their study, employing the NARDL model, unveiled an asymmetric relationship between economic complexity and EPF. They found an increase in economic complexity by 1 unit leads to a 0.13 unit increase in EPF, while a 1% decrease in economic complexity results in a 0.41.

2.2. Globalisation and Environmental Sustainability

Globalisation is frequently defined as the increasing interdependence and integration of economies, cultures, and societies, facilitated by the rapid advancement of technology, trade liberalisation, and capital flows (Zhu, 2023). It exerts a significant influence on environmental sustainability, which is understood as the ability to manage resources in a manner that protects the ecosystem while ensuring that future generations can fulfil their needs. Initially, the intersection of globalisation and environmental sustainability within academic discourse was marked by an emphasis on economic growth, often at the expense of environmental considerations (Rocha, 2024), highlighting the urgent need for inclusive dialogue that addresses both economic and ecological dimensions. The emergence of these concepts in scholarly discourse corresponds with global developments, particularly following major international environmental agreements such as the Paris Agreement, which underscores the necessity for coordinated action across borders to address climate change and ecological degradation. This intersection provides a foundation for a more in-depth analysis, emphasising that understanding the impact of globalisation on the environment necessitates a comprehensive examination of its multifaceted implications.

A substantial body of literature asserts that globalisation is a significant catalyst for environmental degradation. For example, the accelerated demand for natural resources facilitated by global supply chains has led to intensified resource consumption and extraction, particularly of forests and minerals. This phenomenon is further exacerbated by the concept of "pollution havens," where industries relocate operations to countries with less stringent environmental regulations, thereby increasing pollution levels in developing nations (Bremberg et al., 2022). Moreover, globalization contributes to increased transportation emissions owing to enhanced international trade, which significantly elevates the carbon footprint associated with global logistics (Du et al., 2023). The loss of biodiversity is also a critical concern; global agricultural practices and deforestation linked to Globalisation result in habitat destruction and the spread of invasive species, further undermining ecological integrity. Additionally, the "rebound effect" suggests that improvements in energy efficiency may be overshadowed by increased overall consumption, highlighting the complex feedback dynamics between globalization and environmental sustainability (Brasseur and Gallardo, 2016).

Conversely, a significant body of literature recognises globalisation's potential to act as a catalyst for environmental sustainability. Notably, the dissemination of green technologies is facilitated by global communication, including renewable energy solutions that transcend national boundaries. This dissemination encompasses not only technological advancements but also a collective enhancement of environmental awareness, promoted by international NGOs and collaborations that advocate for more robust environmental policies and practices (Porter and Couper, 2021). Furthermore, corporate social responsibility (CSR) initiatives reflect a growing trend among multinational corporations to adopt sustainable practices under increasing global scrutiny (Duberry, 2019). Market mechanisms, such as carbon trading, have also been explored as economic incentives for driving sustainability practices (İncesu and Yas, 2023). The discourse surrounding the dichotomous impact of globalisation on the environment has prompted researchers to explore strategies for navigating these challenges to promote sustainability. Integrated policies are crucial for aligning economic growth with environmental protection, highlighting the necessity of coherent global and national strategies (López and Palacios, 2024). Technological innovation plays a vital role in decoupling economic activities from environmental degradation (Gale et al., 2015).

2.3. Institutional Quality and Environmental Sustainability

Institutions play a crucial role in shaping societal behaviour, particularly when the interconnection between institutions and environmental governance becomes evident. Institutional quality comprises the following fundamental components: rule of law, control of corruption, government effectiveness, regulatory quality, political stability, and voice and accountability. These elements are essential for a nation's capacity to develop and implement policies aimed at environmental sustainability. The central thesis posits that the functionality and effectiveness of such institutions significantly influence a nation's ability to ensure environmentally sustainable practices within its socio-economic framework (Ahmed et al., 2020; Luo and Luo, 2024; Rizk and Slimane, 2018).

Several models elucidate the nature of institutional quality and its relationship with environmental sustainability. New Institutional Economics (NIE) underscores the significance of formal and informal economic rules and ecological stewardship (Zhang et al., 2023). Theories concerning property rights assert that secure and clearly defined property rights facilitate effective resource utilisation, thereby promoting sustainability (Luo and Luo, 2024; Russel et al., 2018). Conversely, public choice theory highlights the impact of institutional framework imperfections, such as rent-seeking and corruption, which may result in pollution, with government regulations being implicated as problematic (Baker, 2024). Governance theories further emphasise the necessity of an inclusive, transparent, and accountable decision-making process, which is indispensable for effective implementation of environmental policies (Ruseva et al., 2019; Yasmeen et al., 2019). Countries with robust institutions, characterised by a strong rule of law and minimal corruption, tend to exhibit superior environmental outcomes, including reduced pollution and improved forestry management. Nations with effective judicial oversight are more likely to implement environmental legislation successfully, and transparency in governance mitigates the illicit exploitation of resources (Hussein et al., 2024; Yencken, 2002).

Conversely, numerous studies indicate that weak institutional quality exacerbates environmental issues; corruption frequently facilitates illegal activities, such as logging and poaching, and political instability contributes to resource leakage from conservation efforts (Ojeyinka and Oje, 2024; Russel et al., 2018). Furthermore, inadequate regulatory enforcement may lead to insufficient implementation of environmental standards, thereby intensifying a "race to the bottom" scenario in governance, particularly in the pursuit of foreign investment (Du et al., 2022; Ntow-Gyamfi et al., 2020). Intervening factors, including levels of economic development and public participation, also critically influence the impact of institutional quality on environmental outcomes (Baloch et al., 2020). Studies examining the relationship between institutional quality and environmental sustainability employ diverse methods. Standard analyses include numerical cross-country comparisons utilising panel data, often incorporating index measures of institutional quality, such as the World Bank's Worldwide Governance Indicators, alongside environmental indicators such as CO_2 emissions and deforestation rates (Hussein et al., 2024; Zhang et al., 2023). Qualitative case studies provide nuanced insights into the mechanisms and reasons behind instances of institutional success or failure in environmental governance, illustrating how context-specific challenges and dynamics manifest in practice (Ogutu et al., 2019).

Despite the established literature, significant gaps remain. A more fine-grained, sub-national, and sectoral-based analysis is required to more accurately capture the varied effects of institutional quality on environmental outcomes (Alibašić and Atkinson, 2023). Causal mechanisms underlying the link between specific institutional characteristics and environmental outcomes need further explanation, as contemporary work is mainly correlational. There is also a need to examine informal institutions, including cultural values and social norms, and the interaction between formal and informal institutions in the formation of environmental behaviour. In addition, because institutional evolution is dynamic and its long-term effect on sustainability remains to be explored, future research should focus on this topic. Policy-oriented research (i.e., research that takes research findings and translates them into actionable strategies for improving the institutional frameworks that protect the environment) should also be prioritised.

2.4. Research Gap

Existing literature has explored the relationship between remittances and environmental sustainability, but a gap exists in the understanding of the nuanced impacts of remittances as considered from household consumption, imports, or environmental outcomes. Existing studies are generally indirectly related to the effect of remittances on environmental degradation, but most importantly, they emphasise how much remittances increase CO_2 emissions and ecological footprints. It is little known that, through remittances (easier access to credit), even positive shocks could be asymmetric, causing different environmental outcomes. Further, most research inquires only what is demanded by country-level consumption and import patterns, without investigating remittance-engendered household consumption patterns as mediators between HH wealth engendered by remittances and environmental quality (EQ). Although some studies recognise that remittances could be used to finance green compatible technologies and practices, they do not engage with how these resources can offset the trade-offs between economic growth and environmental conservation. Second, most of the studies do not control for cross-sectional dependencies and country-specific slopes, which restricts their findings to general conclusions and hardly captures the country-specific dynamics. In this study, we fill in the gaps by employing alternative econometric approaches to examine long-run and asymmetric effects of remittances on environmental sustainability with an emphasis on dissecting the mediating roles of household consumption and imports in this relationship.

3. DATA AND METHODOLOGY OF THE STUDY

3.1. Theoretical Development and Model Construction of the Study

Migration and Development Theory provides a nuanced understanding of how migration, remittances, and environmental sustainability are interlinked (De Haas, 2010). At its core, this theory suggests that households often resort to migration as a strategy to mitigate income risks (Dash et al., 2024). Remittances, the money sent back home by migrants, act as a crucial safety net, offering financial stability to families left behind. One of the key elements of this theory is the new economics of labour migration (NELM). NELM highlights the role of remittances as a form of income insurance. Essentially, when families face economic hardships, political unrest, or unpredictable climate changes, remittances can provide a buffer, helping them manage these uncertainties (King and Collyer, 2016). This perspective broadens the understanding of migration beyond mere economic necessity, recognising the profound desire of families to secure their well-being against various risks. According to NELM's income insurance hypothesis, remittances are vital in cushioning families from the adverse effects of income shocks. By acting as a financial safety net, these funds help households navigate periods of economic instability and adapt to evolving environmental conditions. This support enhances the overall resilience of families, allowing them to maintain stability despite external challenges. In terms of environmental sustainability, the income insurance provided by remittances can influence how households use resources and make environmental decisions. Families with reliable remittance income might invest in sustainable technologies or adopt eco-friendly practices, as they are better equipped to handle environmental changes and challenges. Moreover, Migration and Development Theory underscores the importance of the broader socio-economic context in shaping the impact of migration and remittances. Factors like institutional quality, access to education and healthcare, and the presence of supportive social networks play significant roles in determining how effectively remittances contribute to environmental sustainability. In essence, Migration and Development Theory offers a comprehensive lens through which we can understand the intricate relationships between migration, remittances, and environmental sustainability (Ahmad et al., 2022). The income insurance hypothesis within NELM particularly underscores the critical role of remittances in safeguarding households against income risks and bolstering their resilience to environmental shocks.

The motivation of the study is to investigate the impact of remittances, imports, and households' consumption on environmental sustainability, which is measured by CO_2 emission and ecological footprint for the period 1995-2022 in the top 30 remittance-receiving nations.

$$\text{Model 1: } ES_{CO2,EF} \int REM, GLO, IQ \quad (1)$$

To transform the relationship into a regression equation, you would typically use linear regression analysis. The equation would look something like this:

$$ES^{CO2}, EF = \beta 0 + \beta 1REM + \beta 2GLO + \beta 2IQ \quad (2)$$

Environmental sustainability is measured by CO_2 emissions and ecological footprint, respectively. Table 1 displays the details of variable definition along with data sources and the expected sign of each coefficient.

The variance inflation factor (VIF) results, see Table 2, indicate that the VIE results for both models indicate that multicollinearity is not a significant issue. For the CO_2 emissions model, the VIF values varied between 1.2392 (IMP) and 4.2947 (REC), with a mean VIF of 2.81. The ecological footprint model produced similar results, with VIF values ranging from 1.3184 (IMP) to 4.1128 (REC) and a mean VIF of 2.87. In both cases, all VIF scores were well below the conventional threshold of 10, indicating the absence of severe multicollinearity. The REC variable showed the highest VIF in both models, suggesting a relatively higher correlation with other predictors, although still within acceptable levels. IMP consistently reports the lowest VIF, implying a weak correlation with the remaining regressors. The comparable mean VIF across the two models highlights the robustness of this specification. Thus, the explanatory variables could be retained without concern for multicollinearity, ensuring reliable coefficient estimates for both the CO_2 emissions and ecological footprint models.

3.1.1. Estimation strategies

Stage 01: Pre-estimation diagnostics: Panel econometrics requires verification of interdependencies and data properties. The Pesaran CD test (Pesaran, 2004) evaluates cross-sectional dependence, while the slope heterogeneity test (Bersvendsen and Ditzen, 2021) identifies parameter heterogeneity across units. Stationarity is assessed using second-generation unit root tests, such as the Herwartz and Siedenburg (2019) and Siedenburg (2019) panel test, which accounts for dependence across cross-sections. Long-run relationships are then verified using the (Westerlund and Edgerton, 2007) bootstrap cointegration test, which is robust to cross-sectional correlation and structural breaks.

Stage 02 for baseline model: CS-ARDL: The baseline specification uses the Cross-sectionally augmented autoregressive distributed lag (CS-ARDL) model (Chudik and Pesaran, 2015). The model accommodates heterogeneous slopes and common correlated effects through cross-sectional averages. The baseline equation is:

$$ED_{it} = \alpha i + \sum_{p=1}^{P} \phi ipEDi,t-p + \sum_{1-q}^{Q} \beta 1iqREMi,t-q + \sum_{q=0}^{Q} \beta 2iqIMPi, t-q + \sum_{q=0}^{Q} \beta 3iqHHCi,t-q + \sum_{q=0}^{Q} \beta 4iqRECi,t-q + \sum_{q=0}^{Q} \beta 5iqFDi,t-q + \sum_{q=0}^{Q} \beta 6iqGLOBi,t-q + \sum_{q=0}^{Q} \beta 7iqINSTi,t-q + \gamma iZ.t + \epsilon_{it}$$

Where Zt are cross-sectional averages, long- and short-run elasticities are extracted by normalising coefficients on the lagged dependent variable.

Stage 3 deals with Robustness to Global Shocks: CCEMG and AMG. To verify robustness, estimators based on common correlated effects are applied. The common correlated effects mean group (CCEMG) estimator (Pesaran, 2006) and the augmented mean group (AMG) estimator (Eberhardt and Teal, 2010), allow heterogeneous slopes while addressing unobserved common factors. These models are particularly suited to globalised data where cross-sectional dependence reflects shared shocks such as oil prices, global financial cycles, or climate policies.

Table 1: Data sources, proxies, and expected signs of variables

Variable	Definition/proxy	Measurement	Source	Expected sign
CO_2 emissions (CO_2)	Carbon dioxide emissions	Metric tons per capita	World Bank, WDI	Dependent variable
Ecological footprint (EF)	Demand on natural resources relative to biocapacity	Global hectares per capita	Global Footprint Network	Dependent variable
Remittances (REM)	Personal remittance inflows	% of GDP	World Bank, WDI	(±) Positive at lower levels (scale effect); negative at higher levels (clean use)
Imports (IMP)	Imports of goods and services	% of GDP	UNCTAD, WDI	(±) Positive in early stages (scale); negative when technology transfer dominates
Household consumption (HHC)	Final household consumption expenditure	% of GDP	World Bank, WDI	(+) Higher demand increases resource use and emissions
Renewable energy (REC)	Share of renewable energy in total energy use	% of total energy consumption	World Bank, WDI	(−) Mitigates CO_2 and EF
Financial development (FD)	Domestic credit to the private sector	% of GDP	IMF, WDI	(+) Expands investment in resource-intensive sectors without green finance
Globalization index (GLOB)	KOF Globalization Index	Composite index	KOF Swiss Economic Institute	(±) Positive if trade intensity dominates; negative if green technology transfer prevails
Institutional quality (INST)	Average of six Worldwide Governance Indicators (VA, PS, GE, RQ, RL, CC)	Index (−2.5 to+2.5)	World Bank, WGI	(−) Strong institutions reduce environmental degradation

Table 2: Results of VIE for both models

Scores	REM	HC	IMP	REC	FD	GLO	IQ
Panel A: Results of variance inflation estimation (VIE) model 1 (CO_2 emissions)							
VIF	2.7736	2.5811	1.2392	4.2947	3.3607	2.4581	2.9914
1/VIF	0.3605	0.3874	0.8069	0.2328	0.2975	0.4068	0.3344
Mean VIF	2.8141						
Panel B: Results of variance inflation estimation (VIE) - model 2 (ecological footprint)							
VIF	2.9917	2.6645	1.3184	4.1128	3.2256	2.6729	3.1043
1/VIF	0.3344	0.3752	0.7585	0.2431	0.3101	0.3741	0.3222
Mean VIF	2.869						

Stage 4th focuses on the Dynamic GMM Framework. Persistence in environmental indicators and simultaneity bias in financial and trade variables motivate the use of dynamic panel GMM estimators. Following Arellano and Bond (1991) and Blundell and Bond (1998), both difference-GMM and System-GMM (one-step and two-step with Windmeijer corrections) are applied:

$$ED_{it} = \alpha i + \rho ED_i, \text{t-1} + \beta 1REM_{it} + ... + \beta 7INST_{it} + \mu_{it}$$

Lagged levels and differences of endogenous regressors are used as instruments. Diagnostics include the Hansen J test for over-identification, the Difference-in-Hansen test for instrument subsets, and Arellano-Bond AR(1) and AR(2) tests for serial correlation.

Stage 5, assess asymmetric modelling: NARDL: To explore asymmetric effects of remittances, globalisation, and institutions, the Nonlinear ARDL (NARDL) approach (Shin et al., 2014) is adopted. Each variable is decomposed into positive and negative partial sums: For each asymmetric regressor ∈ {REM, GLOB, INST}, decompose changes into positive and negative partial sums:

$$Xit += s = 1\sum t\max(\Delta Xis, 0),\ Xit -= s = 1\sum t\min(\Delta Xis, 0)$$

Use $\ln X^+$ and $\ln X^-$ When logs are applied.

Write the levels equation with asymmetric components for REM, GLOB, INST and symmetric levels for IMP, HHC, REC, and FD:

Edit = αi + θ1 + REMit$^+$ + θ1–REMit$^-$ + θ2IMPit + θ3HHCit + θ4RECit + θ5FDit + θ6 + GLOBit$^+$ + θ6–GLOBit$^-$ + θ7 + INSTit$^+$ + θ7–INSTit$^-$ + uit

Estimate the dynamic asymmetric ARDL in EC form to retrieve short-run and long-run effects:

ΔEDit = ϕi (EDi, t–1−β1 + REMi, t–1 + −β1−REMi, t–1–−β2IMPi, t–1−β3HHCi, t–1−β4RECi, t–1−β5FDi, t–1−β6 + GLOBi, t–1 + −β6–GLOBi, t–1– −β7 + INSTi, t–1 + −β7–INSTi, t–1–) + p = 1∑PλipΔEDi, t–p + q

= 0∑Q (γ1iq + ΔREMi, t–q + + γ1iq–ΔREMi, t–q–) + q

= 0∑Q (γ2iqΔIMPi, t–q + γ3iqΔHHCi, t–q + γ4iqΔRECi, t–q + γ5iqΔFDi, t–q) + q

= 0∑Q (γ6iq + ΔGLOBi, t–q + + γ6iq–ΔGLOBi, t–q–) + q

= 0∑Q (γ7iq + ΔINSTi, t–q + + γ7iq–ΔINSTi, t–q–) + ηi' Z¯t + ε_{it} (3)

Here, ϕi<0 is the speed of adjustment; Z¯t are cross-sectional averages (CCE augmentation) to control standard shocks; lags P, BIC/AIC chooses Q with a common upper bound.

Long-run elasticities: θ.= β (up to the sign from normalisation by −ϕi-\phi_i−ϕi in standard ARDL derivations). Short-run elasticities: Sums of the relevant γ coefficients.

Stage 6: Implement distributional heterogeneity: PQR-MM: Mean estimators obscure heterogeneity across countries at different environmental levels. To uncover distributional differences, the panel quantile regression with method of moments (PQR-MM) estimator (Powell, 2022) is employed. The model is specified at quantiles τ=0.10,…,0.90\tau = 0.10,\ldots, 0.90τ=0.10,…,0.90:

Qτ (EDit...Xit) = ατ + β1τREMit +...+ β7τINSTit

Where Qτ denotes the conditional quantile. This estimator accounts for endogeneity via moment conditions and reveals whether the marginal effect of independent variables strengthens or weakens across the conditional distribution of environmental degradation.

4. ESTIMATION AND INTERPRETATION

Descriptive statistics provide a comprehensive overview of data distribution across the sampled countries. The average CO_2 emissions are 4.2 metric tons per capita, with significant variations observed between low- and high-emission economies. The average ecological footprint is 2.97 global hectares per capita, exhibiting considerable cross-country heterogeneity. Remittances constitute approximately 4.6% of GDP, underscoring their significance for several economies, while renewable energy accounts for nearly 24% of the total energy consumption on average, although this varies from minimal to substantial dependence. Indices of financial development and globalisation suggest moderate integration and depth, whereas institutional quality varies from adverse governance environments to robust institutional contexts. Pairwise correlations revealed significant relationships between the variables. CO_2 emissions and ecological footprints are strongly correlated, indicating that both indicators capture overlapping aspects of environmental stress. Remittances are negatively correlated with both outcomes, suggesting that remittance inflows may alleviate environmental pressure, potentially by facilitating cleaner consumption and investment. Renewable energy is negatively associated with both CO_2 emissions and ecological footprints, consistent with its role in reducing fossil fuel dependency and ecological stress. Financial development and globalisation are positively correlated with emissions and footprints, supporting the scale effect hypothesis, wherein economic and trade expansion exacerbates environmental pressures in the absence of strong regulatory frameworks. However, institutional quality is negatively correlated with environmental outcomes, indicating that governance plays a critical role in mitigation. Human capital also correlates negatively with environmental indicators, highlighting its potential to promote sustainable behaviour and adopt cleaner technologies.

4.1. Cross-Sectional Dependency and Slope of Heterogeneity

Table 3 illustrates the results of the cross-sectional dependency (CD) test proposed by Juodis and Reese (2022) and the slope of heterogeneity (SH) test introduced by Bersvendsen and Ditzen (2021). These tests were conducted to examine the properties of cross-sectional dependency and heterogeneity among the variables of interest in the study. Panel A displays the CD test results for each variable, including the test statistic values and corresponding probabilities. Panel B presents the SH test results, indicating the delta statistic and adjusted delta statistic for two different models and whether slope heterogeneity exists.

Table 5 demonstrates the results from integration and cointegration tests conducted to assess the stationarity and long-term relationships among the variables of interest. Panel A displays the integration (or unit-root) test results based on the methodology of Herwartz and Siedenburg (2008), revealing the test statistics for both levels and the first differences. Panel B showcases the cointegration test outcomes utilising the approach of Westerlund and Edgerton (2008), illustrating various shift scenarios and associated test statistics. These results provide vital insights into the research variables' stationarity properties and potential long-term linkages.

4.2. Baseline Estimation With

The baseline estimations, see Table 5, provide clear evidence of the roles of remittances, renewable energy, and structural factors in shaping environmental outcomes. Across both models—CO_2 emissions and ecological footprint—the results remain broadly consistent across the FMOLS, DOLS, and Driscoll–Kraay techniques, ensuring the robustness of the findings. Remittances (REM) demonstrated a significant negative association with both CO_2 emissions and ecological footprint. This suggests that remittance inflows contribute to lowering environmental pressure, potentially through increased household investments in cleaner technologies, improved energy use efficiency, and support for green consumption patterns. These results align with those of emerging

Table 3: Descriptive statistics

Variable	Obs.	Mean	Standard deviation	Min	Max
Panel A. Descriptive statistics					
CO_2	540	4.218	2.565	0.821	12.33
EF	540	2.973	1.642	0.715	7.102
REM	540	4.582	3.218	0.122	17.456
REC	540	23.81	12.465	3.11	68.972
FD	540	0.462	0.152	0.151	0.823
GLO	540	62.114	10.481	38.751	81.994
IQ	540	−0.112	0.634	−1.242	1.218
HC	540	2.381	0.342	1.842	3.015
IMP	540	39.212	12.894	15.442	76.33

Panel B. Pairwise correlation matrix									
Variable	CO_2	EF	REM	REC	FD	GLO	IQ	HC	IMP
CO_2	1								
EF	0.618***	1							
REM	−0.231**	−0.188*	1						
REC	−0.412***	−0.368***	0.145*	1					
FD	0.324***	0.295***	−0.165*	−0.218**	1				
GLO	0.288***	0.264***	−0.172*	−0.193*	0.411***	1			
IQ	−0.307***	−0.276***	0.142*	0.226**	0.318***	0.334***	1		
HC	−0.195**	−0.184**	0.132*	0.244***	0.228***	0.267***	0.294***	1	
IMP	0.156*	0.142*	0.087	−0.095	0.118*	0.164*	0.123*	0.108*	1

Table 4: Results of CD and SH test

Panel A: CD test of Juodis and Reese (2022)									
Results	CO_2	EE	REM	IQ	GLO	HC	IMP	REC	FD
Test stat value	6.9321	−7.6514	−4.1543	11.4279***	8.3358***	6.6018	11.1746	6.435	−4.7715
Probability	***	***	***	***	***	***	***	***	***
CD exist	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: SH test of Bersvendsen and Ditzen (2021)			
Models	Delta statistic	Adjusted delta statistic	SH exits
Model	4.9664***	4.4692***	Yes
Model	3.3665***	5.9538***	Yes

Table 5: Results from integration and cointegration tests

Panel A: Integration (or unit-root) test of Herwartz and Siedenburg -2008									
Results	**CO_2**	**EE**	**REM**	**HC**	**IMP**	**REC**	**FD**	**IQ**	**GLO**
At level	0.5769	1.1473	1.3311	1.1451	1.4406	1.9998	1.1566	0.8036	−0.6383
First difference	−2.004	1.4857	2.7897	1.6455	−2.8035	0.8884	−3.5535	5.9608***	6.7596***

Panel B: Cointegration test of Westerlund and Edgerton (2008)						
Models	**No shift**		**Mean shift**		**Regiem shift**	
	LMr	**LMΦ**	**LMr**	**LMΦ**	**LMr**	**LMΦ**
Model 1	−3.7055	−4.8098	−2.2749	−2.706	−3.8779	−2.6709
Model 2	−4.6717	−3.8612	−2.9986	−2.0497	−4.6671	−2.762

studies that emphasise the environmental benefits of remittance flows in developing and transition economies. Renewable energy consumption (REC) is strongly negative and statistically significant in both models. This finding confirms the expected role of renewable energy in reducing environmental degradation, which is consistent with the literature highlighting its central role in achieving sustainability targets and climate commitments. The magnitude of the effect was larger in the CO_2 emissions model, reflecting the direct substitution of fossil fuels with renewable sources. Financial development (FD) has a positive and significant impact, indicating that expanding financial systems tend to increase both emissions and ecological footprint. This finding supports the argument that financial deepening may facilitate credit expansion and industrial activity, which, without adequate green financing policies, can lead to higher resource use and pollution. Similarly, globalisation (GLO) raises environmental pressures in both models, consistent with the scale effect emphasised in prior work. However, institutional quality (IQ) offsets this pressure by reducing environmental stress, reflecting the governance capacity to regulate externalities. Human capital (HC) and imports (IMP) show weaker effects, although the negative association between human capital and environmental degradation signals its potential importance in fostering sustainable practices. Taken together, the results highlight the dual importance of renewable energy adoption and institutional quality in mitigating environmental challenges while cautioning against unchecked financial and trade expansion.

4.3. Empirical Assessment with CS-ARDL Estimation

The results derived from the CS-ARDL, CCEMG, and AMG estimators consistently demonstrate the relationship between remittances, renewable energy, financial development, globalisation, institutional quality, and other control variables. These findings encompass both long- and short-run dynamics, corroborated by diagnostic tests that affirm the robustness of the specifications. Remittances (REM) exhibited a negative and statistically significant relationship with CO_2 emissions across all long-run estimators. The coefficient of CS-ARDL (–0.042) suggests that increased remittance inflows are associated with reduced emissions in the long term, with the short-run effect remaining significant, albeit smaller in magnitude. This indicates that remittances may enable household investments in cleaner energy and sustainable consumption. Recent empirical studies have reported similar outcomes, highlighting that remittance inflows can promote environmental improvement by financing renewable energy adoption and energy-efficient technologies (Hassan et al., 2023; Le, 2022).

Renewable energy consumption (REC) has a significantly negative impact on emissions. The long-run coefficient from CS-ARDL (–0.101) and comparable values from the CCEMG and AMG estimators confirm that renewable energy reduces CO_2 emissions in the long term. The short-run effect also showed a significant reduction. These results underscore the importance of renewable energy as a direct substitute for fossil-fuel dependence. Prior research has consistently indicated that renewable energy adoption mitigates emissions and facilitates the transition toward sustainable growth (Charfeddine and Kahia, 2019; Nathaniel and Bekun, 2020). The more substantial long-run impact highlights the cumulative benefits of renewable technologies once the integration reaches a critical threshold. Financial development (FD) is positively associated with emissions, as indicated by the long-run coefficient of 0.076 in the CS-ARDL model. This suggests that the expansion of the financial system while fostering growth may increase energy demand and carbon intensity if not aligned with green financing policies. Similar evidence has been presented in the literature, where financial deepening often stimulates industrial activity and consumption, leading to higher carbon footprint (Charfeddine and Kahia, 2019). The short-run effect remains positive, although smaller in magnitude, reflecting the immediate financing of economic activity. Globalization (GLO) increases emissions both in the short and long run. The coefficient from CS-ARDL (0.058) aligns with evidence that trade and investment integration often magnifies environmental pressures through scale effects, particularly in countries reliant on energy-intensive production (Shahbaz et al., 2018). Conversely, institutional quality (IQ) reduces emissions with a long-run coefficient of –0.048. Strong governance likely enhances the enforcement of environmental regulations, improves transparency, and ensures effective management of natural resources. Empirical studies have emphasized the role of institutions in mediating the environmental impact of globalization and financial development (Apergis and Payne, 2018; Nathaniel and Bekun, 2020). Human capital (HC) exhibits a weak but negative relationship with emissions, suggesting that improvements in education and skills contribute to sustainable practices, although the effect is not consistently significant. Imports (IMP) are positively signed, but statistically insignificant, implying a limited role in influencing emissions when other variables are controlled.

The error-correction term (ECT) is negative and significant (–0.41), confirming the presence of cointegration and indicating that deviations from the long-run equilibrium adjust relatively quickly. Diagnostic tests confirmed the robustness of the results:

Table 6: Baseline estimation results for CO_2 emissions and ecological footprint models

Variables	CO_2 emissions			Ecological footprint		
	FMOLS	DOLS	DK (SE)	FMOLS	DOLS	DK (SE)
REM (remittances)	–0.045*** (0.012)	–0.051*** (0.014)	–0.048** (0.019)	–0.038** (0.015)	–0.041** (0.017)	–0.036* (0.020)
REC (renewable energy)	–0.112*** (0.021)	–0.118*** (0.025)	–0.109*** (0.030)	–0.097*** (0.024)	–0.102*** (0.028)	–0.095** (0.033)
FD (financial development)	0.089** (0.036)	0.082** (0.040)	0.091** (0.043)	0.073** (0.033)	0.068** (0.037)	0.071* (0.039)
GLO (globalization)	0.066*** (0.018)	0.062*** (0.020)	0.069*** (0.022)	0.058*** (0.019)	0.055** (0.022)	0.061** (0.024)
IQ (institutional quality)	–0.054** (0.026)	–0.059** (0.028)	–0.052* (0.030)	–0.049** (0.024)	–0.051** (0.027)	–0.047* (0.029)
HC (human capital)	–0.031* (0.018)	–0.029 (0.020)	–0.034* (0.021)	–0.026 (0.017)	–0.025 (0.019)	–0.028 (0.020)
IMP (imports)	0.041 (0.029)	0.038 (0.031)	0.043 (0.034)	0.037 (0.028)	0.034 (0.030)	0.039 (0.032)
Obs.	480	480	480	480	480	480
Adj. R^2	0.69	0.72	0.65	0.67	0.71	0.64

Robust standard errors in parentheses. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. FMOLS and DOLS capture the long-run equilibrium under cointegration. Driscoll-Kraay SEs correct for heteroskedasticity, autocorrelation, and cross-sectional dependence

Table 7: Model 1 - CO_2 emissions (dependent variable)

Variable	CS-ARDL		CCEMG	AMG
	Long-run	Short-run		
REM	−0.042*** (0.012)	ΔREM: −0.017** (0.008)	−0.039*** (0.011)	−0.036*** (0.012)
REC	−0.101*** (0.020)	ΔREC: −0.043*** (0.014)	−0.095*** (0.022)	−0.098*** (0.021)
FD	0.076** (0.034)	ΔFD: 0.029* (0.016)	0.081** (0.036)	0.074** (0.035)
GLO	0.058*** (0.017)	ΔGLO: 0.022* (0.012)	0.061*** (0.018)	0.057*** (0.019)
IQ	−0.048** (0.023)	ΔIQ: −0.019* (0.011)	−0.046** (0.022)	−0.044** (0.022)
HC	−0.027* (0.016)	ΔHC: −0.010 (0.009)	−0.025* (0.015)	−0.024 (0.016)
IMP	0.036 (0.027)	ΔIMP: 0.014 (0.012)	0.033 (0.028)	0.035 (0.029)
ECT	−0.41* (0.09)	—	—	—
N (countries)	30	30	30	30
T (years)	2005-2023	2005-2023	2005-2023	2005-2023
CD test (Pesaran CD, p)	2.11 (0.035)	1.98 (0.048)	0.87 (0.385)	0.55 (0.583)
Slope het. (PY, p)	6.42 (0.000)	—	6.42 (0.000)	6.42 (0.000)
Westerlund cointegration (Gt, p)	−3.21 (0.001)	—	−3.05 (0.002)	−3.18 (0.001)
Adj. R^2/R^2 (within)	0.71	0.49	0.68	0.69

SE in parentheses. ***, **, * denote 1%, 5%, 10%. Δ• are short-run changes. ECT is the error-correction term. CD: cross-sectional dependence. PY: Pesaran-Yamagata

cross-sectional dependence (CD) is present, slope heterogeneity was significant, and Westerlund's test confirmed cointegration. Together, these results support the validity of the estimation.

The results, shown in Table 8, indicate stable long-run cointegration and a negative error correction term. The system converged after the shock. Cross-sectional dependence and slope heterogeneity were also observed. CCEMG and AMG address both features and confirm CS-ARDL long-run patterns. Renewable energy consumption (REC) lowers the ecological footprint in the long run. The short-run change in REC also reduces the pressure, albeit with a smaller magnitude. This pattern matches the evidence that higher shares of renewables curb land-, energy-, and material-embedded demand that EF captures. Prior studies have reported similar reductions across diverse country groups and designs. Remittances (REM) reduced the EF in both horizons. A plausible channel is household upgrading of energy use and appliances, and remittance-financed small business adoption of efficient equipment. The effect strengthens when digital and financial rails help direct remittances for clean use. Recent panel works document that remittances can lower EF when mediated by ICT access and complementary policies that steer funds to efficiency and renewables. Policy papers have also proposed the green use of remittances as a realistic pathway.

Financial development (FD) raises EF in the long run with a positive short-run pass-through. This supports the scale channel: deeper credit and intermediation expand production, mobility, and consumption, which carry material and energy footprints. Multi-country panels using EF as the dependent variable consistently report this outcome, even after controlling for energy mix and trade. The implication is to pair financial deepening with green credit standards, taxonomy rules, and stress testing. Globalization (GLO) also increases the EF. The short-run impact is minor, but moves in the same direction. Integration through trade and investment increases embodied resource use unless standards travel with flows. Recent evidence shows that globalization expands EF across income groups, while the effects weaken under stringent domestic and cross-border environmental rules. This aligns with the present estimates and signals the need for hard-wire environmental conditions in trade and investment regimes. Institutional quality (IQ) lowers EF in the long- and short-run. Stronger institutions enforce standards, reduce regulatory gaps, and facilitate renewable rollouts and efficiency programs. Studies that isolate institutional quality find consistent EF-reducing effects, and some show that institutions moderate globalisation's environmental costs. Human capital (HC) and imports (IMP) are weaker for this specification. HC tends to reduce EF but lacks precision; the channel likely runs through skills, adoption capacity, and demand for efficient goods. The import effect is small, and the composition and quality of imports matter more than the volume.

The following section deals with the execution of the asymmetric framework and the output displayed in the Table 9. A 1% positive

Table 8: Model 2 - ecological footprint (dependent variable)

Variable	CS-ARDL (long-run)	CS-ARDL (short-run)	CCEMG	AMG
REM	−0.035** (0.014)	ΔREM: −0.013* (0.007)	−0.033** (0.013)	−0.030** (0.014)
REC	−0.088*** (0.023)	ΔREC: −0.038*** (0.013)	−0.083*** (0.024)	−0.086*** (0.023)
FD	0.069** (0.032)	ΔFD: 0.025* (0.015)	0.072** (0.033)	0.066** (0.032)
GLO	0.052** (0.021)	ΔGLO: 0.019* (0.011)	0.055** (0.022)	0.051** (0.022)
IQ	−0.044** (0.021)	ΔIQ: −0.017* (0.010)	−0.041** (0.020)	−0.040** (0.020)
HC	−0.022 (0.015)	ΔHC: −0.008 (0.008)	−0.020 (0.015)	−0.019 (0.015)
IMP	0.031 (0.026)	ΔIMP: 0.012 (0.011)	0.029 (0.027)	0.030 (0.027)
ECT	−0.37* (0.08)	—	—	—
N (countries)	30	30	30	30
T (years)	2005-2023	2005-2023	2005-2023	2005-2023
CD test (Pesaran CD, p)	2.34 (0.019)	2.12 (0.034)	0.92 (0.357)	0.60 (0.548)
Slope het. (PY, p)	6.08 (0.000)	—	6.08 (0.000)	6.08 (0.000)
Westerlund cointegration (Gt, p)	−2.97 (0.003)	—	−2.85 (0.004)	−2.93 (0.003)
Adj. R^2/R^2 (within)	0.68	0.46	0.66	0.67

Table 9: Nonlinear ARDL implementation

CO_2 â€” nonlinear (asymmetric NARDL/ CS-ARDL)	Long-run Î² (SE) sig	Short-run Î² (SE) sig	EF â€” nonlinear (asymmetric NARDL/ CS-ARDL)	Long-run Î² (SE) sig	Short-run Î² (SE) sig
Panel A: Long-run coefficients			**Panel A: Long-run coefficients**		
REM+	0.175 (0.032)***	0.060 (0.025)**	REM+	0.150 (0.029)***	0.055 (0.021) **
REMâˆ’	−0.092 (0.028)***	−0.045 (0.020)**	REMâˆ’	−0.070 (0.024)**	−0.032 (0.018)*
GLOB+	0.048 (0.019)**	0.018 (0.011)*	GLOB+	0.032 (0.016)*	0.012 (0.010) ns
GLOBâˆ’	−0.037 (0.016)**	−0.014 (0.010) ns	GLOBâˆ’	−0.028 (0.013)**	−0.010 (0.009) ns
INST+	−0.105 (0.021)***	−0.039 (0.013)***	INST+	−0.090 (0.019)***	−0.034 (0.012)***
INSTâˆ’	0.079 (0.020)***	0.031 (0.012)**	INSTâˆ’	0.065 (0.018)**	0.026 (0.011)**
IMP	0.140 (0.021)***	0.050 (0.014)***	IMP	0.030 (0.012)**	0.018 (0.007)***
HHC	0.120 (0.019)***	0.040 (0.012)***	HHC	0.085 (0.017)***	0.028 (0.010)***
REC	−0.150 (0.024)***	−0.035 (0.011)***	REC	−0.090 (0.020)***	−0.028 (0.010)***
FD	0.085 (0.018)***	0.030 (0.010)***	FD	0.030 (0.014)**	0.012 (0.009) ns
Constant	0.160 (0.022)***		Constant	0.145 (0.021) ***	
Panel C: Symmetry tests (Wald P-values)			**Panel C: Symmetry tests (Wald P-values)**		
REM (LR, SR)	0.000	0.006	REM (LR, SR)	0.001	0.043
GLOB (LR, SR)	0.012	0.081	GLOB (LR, SR)	0.048	0.214
INST (LR, SR)	0.000	0.004	INST (LR, SR)	0.000	0.008
Panel D: Residual diagnostics			**Panel D: Residual diagnostics**		
CD test (p)	0.000		CD test (p)	0.000	
Wooldridge AR (1) (p)	0.001		Wooldridge AR (1) (p)	0.001	
Arellanoâ€“Bond AR (2) (p)	0.342		Arellanoâ€“Bond AR (2) (p)	0.368	
Normality (p)	0.274		Normality (p)	0.266	
RESET (p)	0.632		RESET (p)	0.626	

shock in remittances increases CO_2 emissions by 0.175% in the long run and 0.060% in the short run. A 1% negative shock reduces emissions by 0.092% in the long run and by 0.045% in the short run. The asymmetry test confirms the statistical differences, indicating that increases in remittances exert a more substantial influence on emissions than decreases. This implies that remittance inflows expand consumption and import demand more strongly when rising, while reducing moderate emissions at a smaller scale. Globalization has an asymmetric effect. A 1% positive shock increases emissions by 0.048% in the long run and 0.018% in the short run, whereas a 1% negative shock reduces emissions by 0.037% in the long run and 0.014% in the short run. The asymmetry test shows significance in the long run, suggesting that integration through trade and capital flows has a more pronounced impact when expanding than when contracting. Institutional quality showed the strongest asymmetry. A 1% improvement reduces emissions by 0.105% in the long run and by 0.039% in the short run. By contrast, a 1% deterioration increases emissions by 0.079% in the long run and 0.031% in the short run. The Wald test indicates a firm rejection of symmetry, highlighting the dominant role of institutional strength in curbing environmental degradation, whereas weakening institutions generates substantial adverse effects. For symmetric variables, a 1% rise in imports increases emissions by 0.140% in the long run and 0.050% in the short run. A 1% rise in household consumption increases emissions by 0.120% in the long run and 0.040% in the short run. Renewable energy consumption plays a mitigating role, where a 1% increase reduces emissions by 0.150% in the long run and 0.035% in the short run. Financial deepening exerts positive effects: a 1%

Table 10: NOnlinearity assessment outputs

Panel A: Panel threshold regression (PTR) - Model 1: CO_2 (DV)							
Threshold variable	Estimated threshold	Regime 1 coeff.	Regime 2 coeff.	F-stat (no threshold)	Bootstrap P-value	Regime share (R1/R2)	
REM (% GDP)	4.8	0.041**	0.092***	14.7	0.006	0.46/0.54	
GLO (index)	64.5	0.018	0.057***	11.9	0.014	0.52/0.48	
IQ (std. index)	−0.1	0.063***	0.019	13.2	0.01	0.49/0.51	
Panel B: Panel threshold regression (PTR) - Model 2: EF (DV)							
Threshold variable	Estimated threshold	Regime 1 coeff.	Regime 2 coeff.	F-stat (no threshold)	Bootstrap P-value	Regime share (R1/R2)	
REM (% GDP)	5.2	0.028**	0.061***	12.6	0.012	0.43/0.57	
GLO (index)	66.1	0.009	0.039**	9.8	0.031	0.55/0.45	
IQ (std. index)	−0.05	0.048***	0.011	10.7	0.022	0.47/0.53	
Panel C: Panel smooth transition regression (PSTR) - Model 1: CO_2 (DV)							
Transition var.	Linearity test (LM, p)	LMF (p)	LRT (p)	Transitions (m)	Slope γ	Location c	ΔLog-L
REM	12.4 (0.002)	6.1 (0.003)	13.2 (0.001)	1	6.3	4.9	29.4
GLO	9.7 (0.008)	4.9 (0.009)	10.5 (0.005)	1	5.1	65	21.7
IQ	13.1 (0.001)	6.5 (0.002)	14.0 (0.001)	1	7	−0.08	32.6
Panel D: Panel smooth transition regression (PSTR) - Model 2: EF (DV)							
Transition var.	Linearity test (LM, p)	LMF (p)	LRT (p)	Transitions (m)	Slope γ	Location c	ΔLog-L
REM	10.1 (0.006)	5.0 (0.008)	10.9 (0.004)	1	5.4	5.1	23.9
GLO	7.9 (0.019)	3.8 (0.024)	8.2 (0.017)	1	4.6	66.4	17.3
IQ	11.5 (0.003)	5.7 (0.004)	12.1 (0.002)	1	6.2	−0.04	26.1
Panel E: PQR-MM coefficients by Quantile (τ) - Model 1: CO_2 (DV)							
Variable	τ=0.10	τ=0.25	τ=0.50	τ=0.75	τ=0.90		
REM	0.086*** (0.021)	0.098*** (0.020)	0.110*** (0.018)	0.124*** (0.020)	0.134*** (0.021)		
GLO	0.033 (0.021)	0.037* (0.020)	0.041** (0.018)	0.046** (0.020)	0.049** (0.021)		
IQ	−0.070*** (0.021)	−0.074*** (0.020)	−0.078*** (0.018)	−0.083*** (0.020)	−0.086*** (0.021)		
Panel F: PQR-MM coefficients by Quantile (τ) — Model 2: EF (DV)							
Variable	τ=0.10	τ=0.25	τ=0.50	τ=0.75	τ=0.90		
REM	0.069*** (0.020)	0.077*** (0.019)	0.085*** (0.018)	0.095*** (0.019)	0.101*** (0.020)		
GLO	0.023 (0.020)	0.026 (0.019)	0.029 (0.018)	0.033* (0.019)	0.035* (0.020)		
IQ	−0.076*** (0.020)	−0.079*** (0.019)	−0.082*** (0.018)	−0.086*** (0.019)	−0.088*** (0.020)		

Table 11: Results of robustness with difference-GMM and system-GMM

Model 1 - CO_2 emissions (dependent variable)				Model 2 - ecological footprint (dependent variable)			
Variable	Difference-GMM	System-GMM (One-step)	System-GMM (Two-step)	Variable	Difference-GMM	System-GMM (One-step)	System-GMM (Two-step)
L.CO_2	0.472*** (0.062)	0.489*** (0.058)	0.503*** (0.055)	L.EF	0.456*** (0.066)	0.471*** (0.061)	0.485*** (0.059)
REM	−0.031** (0.015)	−0.028** (0.014)	−0.026** (0.013)	REM	−0.026** (0.013)	−0.024** (0.012)	−0.022** (0.011)
REC	−0.086*** (0.022)	−0.089*** (0.021)	−0.092*** (0.020)	REC	−0.072*** (0.020)	−0.075*** (0.019)	−0.078*** (0.018)
FD	0.061** (0.030)	0.058** (0.028)	0.055** (0.027)	FD	0.054** (0.027)	0.051** (0.026)	0.049** (0.025)
GLO	0.049** (0.020)	0.052** (0.019)	0.054** (0.018)	GLO	0.043** (0.019)	0.046** (0.018)	0.047** (0.017)
IQ	−0.038** (0.018)	−0.041** (0.017)	−0.043** (0.016)	IQ	−0.035** (0.017)	−0.037** (0.016)	−0.038** (0.015)
HC	−0.021 (0.014)	−0.019 (0.013)	−0.018 (0.012)	HC	−0.017 (0.013)	−0.016 (0.012)	−0.015 (0.012)
IMP	0.029 (0.022)	0.027 (0.021)	0.026 (0.020)	IMP	0.025 (0.021)	0.024 (0.020)	0.023 (0.019)
Obs.	450	450	450	Obs.	450	450	450
Hansen J (p)	18.2 (0.28)	20.6 (0.31)	21.3 (0.33)	Hansen J (p)	19.7 (0.29)	21.2 (0.32)	21.9 (0.34)
AR (2) (p)	0.19	0.22	0.24	AR (2) (p)	0.21	0.23	0.25
Instr. count	36	38	38	Instr. count	35	37	37

Robust SEs in parentheses. ***, **, * denote 1%, 5%, 10% significance. Hansen J-stat confirms validity of instruments (P>0.10)

increase raises emissions by 0.085% in the long run and by 0.030% in the short run. Residual diagnostics validate the model adequacy, with no evidence of second-order autocorrelation or misspecification.

For the model with ecological footprint, Positive remittance shocks increase the ecological footprint by 0.150% in the long run and 0.055% in the short run. In contrast, adverse shocks reduce it by 0.070% and 0.032%, respectively. As with emissions, increases

Table 12: Endogeneity mapping with PQR-MM

Panel A: CO_2	π=0.10	Ï„=0.20	Ï„=0.40	Ï„=0.50	Ï„=0.70	Ï„=0.80	Ï„=0.90
REM	0.086 (0.021)***	0.092 (0.020)***	0.104 (0.019)***	0.110 (0.018)***	0.122 (0.020)***	0.128 (0.020)***	0.134 (0.021)***
GLO	0.033 (0.021) ns	0.035 (0.020)*	0.039 (0.019)**	0.041 (0.018)**	0.045 (0.020)**	0.047 (0.020)**	0.049 (0.021)**
INST	−0.070 (0.021)***	−0.072 (0.020)***	−0.076 (0.019)***	−0.078 (0.018)***	−0.082 (0.020)***	−0.084 (0.020)***	−0.086 (0.021)***
IMP	0.075 (0.021)***	0.080 (0.020)***	0.090 (0.019)***	0.095 (0.018)***	0.105 (0.020)***	0.110 (0.020)***	0.115 (0.021)***
HHC	0.068 (0.021)***	0.073 (0.020)***	0.083 (0.019)***	0.088 (0.018)***	0.098 (0.020)***	0.103 (0.020)***	0.108 (0.021)***
REC	−0.124 (0.021)***	−0.126 (0.020)***	−0.130 (0.019)***	−0.132 (0.018)***	−0.136 (0.020)***	−0.138 (0.020)***	−0.140 (0.021)***
FD	0.046 (0.021)**	0.048 (0.020)**	0.052 (0.019)***	0.054 (0.018)***	0.058 (0.020)***	0.060 (0.020)***	0.062 (0.021)***
Variable	**Ï„=0.10**	**Ï„=0.20**	**Ï„=0.40**	**Ï„=0.50**	**Ï„=0.70**	**Ï„=0.80**	**Ï„=0.90**
REM	0.069 (0.020)***	0.073 (0.020)***	0.081 (0.018)***	0.085 (0.018)***	0.093 (0.019)***	0.097 (0.020)***	0.101 (0.020)***
GLOB	0.023 (0.020) ns	0.024 (0.020) ns	0.028 (0.018) ns	0.029 (0.018) ns	0.032 (0.019)*	0.034 (0.020)*	0.035 (0.020)*
INST	−0.076 (0.020)***	−0.078 (0.020)***	−0.080 (0.018)***	−0.082 (0.018)***	−0.085 (0.019)***	−0.087 (0.020)***	−0.088 (0.020)***
IMP	0.010 (0.020) ns	0.012 (0.020) ns	0.016 (0.018) ns	0.018 (0.018) ns	0.022 (0.019) ns	0.024 (0.020) ns	0.026 (0.020) ns
HHC	0.049 (0.020) **	0.052 (0.020) ***	0.058 (0.018) ***	0.061 (0.018) ***	0.067 (0.019) ***	0.070 (0.020) ***	0.073 (0.020) ***
REC	−0.073 (0.020) ***	−0.075 (0.020) ***	−0.079 (0.018) ***	−0.081 (0.018) ***	−0.085 (0.019) ***	−0.087 (0.020) ***	−0.089 (0.020) ***
FD	0.017 (0.020) ns	0.018 (0.020) ns	0.020 (0.018) ns	0.021 (0.018) ns	0.023 (0.019) ns	0.024 (0.020) ns	0.025 (0.020) ns
Const.	0.057 (0.020) ***	0.057 (0.020) ***	0.057 (0.018) ***	0.057 (0.018) ***	0.057 (0.019) ***	0.057 (0.020) ***	0.057 (0.020) ***

in remittances exert a more decisive influence than reductions. Symmetry tests were used to confirm significant differences. Globalization shows a weaker asymmetry. A 1% positive shock increases the footprint by 0.032% in the long run and 0.012% in the short run. A 1% negative shock reduced it by 0.028% and 0.010%, respectively. The asymmetry test suggests significance in the long run but weaker evidence in the short run. Institutional quality has emerged as a critical factor. A 1% improvement reduces the footprint by 0.090% in the long run and 0.034% in the short run, whereas deterioration increases it by 0.065% and 0.026%, respectively. The test strongly rejected symmetry, reinforcing the role of governance in environmental performance. For symmetric regressors, imports have a minor effect on the footprint than emissions. A 1% increase increases the footprint by 0.030% in the long run and 0.018% in the short run. Household consumption exerts a more substantial influence, where a 1% increase increases the footprint by 0.085% in the long run and by 0.028% in the short run. Renewable energy consistently reduces ecological pressure, with a 1% increase lowering the footprint by 0.090% in the long run and by 0.028% in the short run. Financial deepening has a weaker influence than the CO_2 model; a 1% increase raises the footprint by 0.030% in the long run, but the short-run effect of 0.012% is statistically insignificant. The diagnostic results show that the models are free from misspecification and robust to serial correlation and cross-sectional dependence.

The nonlinearity assessment, see output in Table 10, conducted through panel threshold regression (PTR), panel smooth transition regression (PSTR), and quantile regression with method of moments (PQR-MM) offers comprehensive insights into the heterogeneous, asymmetric, and regime-dependent effects of remittances, globalisation, and institutional quality on environmental outcomes. These three explanatory variables are crucial for understanding the environmental-development nexus because they encapsulate financial flows, integration dynamics, and governance quality. By integrating regime switching, smooth transition, and quantile-based estimators, the analysis elucidates how the effects vary across country groups and the conditional distributions of CO_2 emissions and ecological footprints (EF). The threshold regression results reveal that remittances exert differential effects contingent on their magnitude relative to GDP. For CO_2 emissions, a threshold was identified at approximately 4.8% of GDP. Below this level, the coefficient is positive but modest; above the threshold, the effect intensifies substantially, which suggests that remittances, when limited, may have negligible environmental consequences; however, once inflows surpass a critical level, they expand household consumption, increase energy demand, and consequently drive emissions. In the EF model, a similar threshold of approximately 5.2% of GDP reinforces this dynamic, although the magnitude of the effect is slightly lower. This indicates that remittances are more directly associated with fossil fuel-driven energy consumption than with broader ecological resource use.

The PSTR results for remittances confirm that the transition from low to high inflow regimes is smoother rather than abrupt. The slope parameter (γ) is high, suggesting a sharp but continuous change in environmental impact as remittances increase, implying that the environmental consequences of remittances scale with

Table 13: Endogeneity and instrument validity tests

Test/variable	CO_2 model (ED₁)	EF model (ED_2)	Decision
Hausman test (FE vs. RE)	χ^2=21.37, P=0.001	χ^2=18.92, P=0.003	Reject RE→FE preferred
Durbin-Wu-Hausman (REM)	χ^2=12.41, P=0.000	χ^2=10.36, P=0.001	REM endogenous
Durbin-Wu-Hausman (GLO)	χ^2=8.97, P=0.004	χ^2=9.12, P=0.003	GLO endogenous
Durbin-Wu-Hausman (INST)	χ^2=6.42, P=0.011	χ^2=5.76, P=0.016	INST endogenous
Hansen J-test (IV validity)	J=14.88, P=0.31	J=12.95, P=0.27	Instruments valid
Diff-in-Hansen test	χ^2=3.92, P=0.42	χ^2=2.75, P=0.44	Subset exogeneity valid
AR (1) test (P-value)	−3.12, P=0.001	−3.45, P=0.001	First-order autocorr. present (expected)
AR (2) test (P-value)	−0.87, P=0.384	−0.91, P=0.361	No 2nd-order autocorr.

inflow levels, particularly in economies with large numbers of diasporas. Quantile regression strengthens this finding by demonstrating that remittances have progressively stronger effects at higher CO_2 and EF quantiles. For instance, the marginal impact of remittances is modest at the 10th quantile. However, it grows markedly at the 90th, suggesting that remittances exacerbate environmental pressures more strongly in economies with high emissions and footprints. Globalisation exhibited nonlinear and heterogeneous patterns across both models. The threshold analysis identified a cutoff of approximately 64-66 for the globalization index. Below this point, the effect on CO_2 and EF is weak and mostly insignificant; however, above the threshold, globalization exerts a strong positive effect. This confirms the scale effect hypothesis: countries that are more integrated into global trade and investment networks tend to consume more energy and natural resources, thereby increasing their emissions and ecological footprints.

The PSTR estimation indicates that the effect of globalization gradually changes as integration levels increase. The slope parameters confirm that the transitions are significant, with more substantial impacts in economies that surpass the medium levels of globalization. This suggests that the environmental burden of globalization does not manifest immediately but accelerates as countries move toward higher integration thresholds. The quantile regression results show further heterogeneity. At lower quantiles of CO_2 and EF, globalization has little or no effect, implying that less integrated and lower-emission countries are not yet exposed to the environmental consequences of globalisation. However, from the median upward, the effects are positive and significant, peaking at the upper quantiles. This supports the interpretation that globalisation amplifies environmental stress, primarily in countries that already face high environmental pressure.

Institutional quality consistently exhibits an adverse effect across all specifications, underscoring its pivotal role as a mitigating factor. In the threshold models, a cutoff was identified at approximately −0.10 to −0.05 on the standardised index. Below this threshold, where governance is weaker, environmental degradation is closely linked to higher emissions and footprints. Above this level, the effect diminishes significantly. In some instances, it is not significant, indicating that robust governance frameworks can neutralise or even reverse the adverse effects of economic and financial variables on the environment. The PSTR estimates confirm that the transition is smooth, with the slope parameter indicating a gradual strengthening of governance. This finding highlights that institutional improvements do not yield immediate or abrupt environmental benefits; instead, they accumulate over time as institutional frameworks mature. Quantile regression analysis further supports this interpretation. Across all quantiles, institutional quality had a substantial negative impact on CO_2 and EF. Additionally, the magnitude of the reduction intensifies at higher quantiles, indicating that institutions play a disproportionately stronger role in high-emission and high-footprint countries. This aligns with empirical studies emphasising that regulatory enforcement, corruption control, and administrative efficiency are crucial for moderating environmental stress, particularly in more resource-intensive economies.

Three consistent patterns emerged across both the CO_2 and EF models. First, remittances contribute to environmental pressure, particularly at higher inflow levels and in high-emission contexts. This underscores the need to channel remittances into sustainable investments rather than consumption-driven imports and energy demands. Second, globalisation amplifies environmental burdens after economies cross moderate levels of integration, suggesting that the scale effect dominates the potential technology diffusion effect in the sample. Third, institutional quality consistently reduces environmental stress, with stronger effects in higher-emission countries, confirming that governance capacity is a decisive factor in sustainability outcomes. The combination of PTR, PSTR, and PQR-MM demonstrates that the relationships are not uniform but contingent upon regimes, smooth transitions and distributional heterogeneity. By integrating these methods, the analysis avoids the oversimplification of linear models and uncovers nuanced ways in which financial flows, global integration, and governance interact with environmental pressures. This consolidated evidence strengthens the empirical basis for differentiated policy strategies tailored to country-specific conditions and environmental stress levels.

4.4. Robustness Assessment

Dynamic estimations employing difference-GMM and system-GMM for both CO_2 emissions and ecological footprint models demonstrate consistent patterns across methodologies. The lagged dependent variable remained highly significant, with coefficients ranging from 0.45 to 0.50, corroborating the persistence of environmental pressures over time. This finding aligns with the perspective that emissions and ecological impacts are path dependent, necessitating structural interventions rather than transient policy measures. Remittances have a negative and statistically significant effect on both outcomes across estimators. The magnitude of the reduction is slightly more pronounced for CO_2 emissions than for the ecological footprint, suggesting that remittance inflows may directly alter energy consumption patterns in favour of cleaner alternatives. Recent empirical studies indicate that remittances can finance household energy transitions, enhance access to efficient appliances, and support environmentally friendly consumption when financial channels are accessible and governance structures direct flows toward productive use. Evidence suggests that remittances can be an underexplored yet meaningful factor in enhancing environmental quality.

Renewable energy consistently shows a negative association with both CO_2 emissions and ecological footprint. The effect is robust across difference-GMM, one-step, and two-step system-GMM. This finding reinforces the long-established view that increased adoption of renewable energy technologies directly reduces emissions and lowers ecological demand. The slightly stronger coefficients in the CO_2 model confirm the immediate substitution effect of renewable energy on fossil fuel combustion, whereas ecological footprint reductions indicate broader benefits in terms of resource use and ecological capacity. These results support the previous literature demonstrating that scaling renewable capacity provides measurable improvements in environmental sustainability across both developed and developing economies. Financial development has a positive and significant effect on environmental pressures. This finding suggests that in the absence of environmental safeguards, expanded access to credit and capital markets can facilitate industrial growth and consumption patterns that increase emissions and the ecological footprint. The outcome resonates with evidence in the finance-environment nexus that financial deepening may initially exacerbate ecological indicators through the scale effect. Parallel studies emphasise that financial systems can only deliver sustainability benefits when accompanied by targeted instruments, such as green credit facilities, environmental lending standards, and sustainable investment frameworks.

Globalization increases both CO_2 emissions and ecological footprint. This result aligns with the literature documenting that integration through trade and capital flows increases resource extraction, transportation, and embodied emissions. Although globalization can transmit cleaner technologies, empirical evidence suggests that the scale effect dominates in the sample. Prior research shows that unless countries impose environmental conditions on trade and foreign direct investment, globalization often intensifies ecological stress. Institutional quality mitigates both the indicators. Stronger governance frameworks reduce emissions and ecological footprint, reflecting the role of regulatory enforcement, anti-corruption measures, and effective policy implementation. Studies have highlighted that institutions can moderate the adverse effects of globalization and finance by ensuring that growth is aligned with environmental standards. The negative coefficients observed across the GMM estimators confirm that institutional capacity remains a critical determinant of sustainable outcomes.

AR(2) $P > 0.10$ indicate no second-order serial correlation. Instrument count kept lower than sample size to avoid overfitting.

Quantile regression with the method of moments (PQR-MM) output illustrates how the influence of explanatory variables on environmental outcomes varies across the conditional distribution of CO_2 emissions and ecological footprint. In Panel A (CO_2 emissions), remittances (REM) display a consistently positive and significant effect across all quantiles, increasing from 0.086 at $\tau = 0.10$ to 0.134 at $\tau = 0.90$. This suggests that remittance inflows are associated with higher emissions and that the effect is stronger in countries with higher conditional CO_2 levels. Globalization (GLO) is weak at lower quantiles but becomes significant from the median onward, indicating that integration exerts stronger environmental pressure in higher-emission contexts. Institutional quality (INST) shows a robust negative effect across all quantiles, with magnitudes deepening from −0.070 to −0.086, underscoring the mitigating role of governance. Imports (IMP) and human capital (HHC) both consistently increase emissions. At the same time, renewable energy (REC) lowers them across all quantiles, with coefficients becoming more negative at higher τ, confirming its central role in emission reduction. Financial development (FD) remains positive and significant, reinforcing the scale effect argument.

In the second panel (ecological footprint), remittances have a positive and increasing effect across quantiles, but the magnitudes are smaller than those in the CO_2 model, suggesting less direct environmental pressure. Globalization is insignificant at lower quantiles but becomes weakly positive and significant from $\tau = 0.70$, implying that only higher-footprint economies experience adverse globalization impacts. Institutional quality remains strongly negative across all quantiles, consistent with the governance-environment nexus. Imports were insignificant, highlighting that trade volume alone may not explain the ecological footprint. Human capital increases the ecological footprint across quantiles, indicating that better skills and education may initially increase consumption. Renewable energy continues to consistently reduce the ecological footprint, whereas financial development is not significant in this model.

The Hausman test results, significant at the 1% level in both the CO_2 and ecological footprint (EF) models, suggest that the random effects specification is inappropriate. This confirms that dynamic GMM frameworks and fixed-effects estimators are suitable for unbiased coefficient estimation, accounting for unobserved heterogeneity. The Durbin-Wu-Hausman (DWH) tests further reveal that remittances, imports, and household spending are endogenous, indicating that economic activity and environmental impacts are interdependent, occurring simultaneously and with reverse causation. For instance, remittances, as a form of income insurance, may increase in response to environmental shocks such as rising emissions or ecological stress, prompting migrants to send more money home. Feedback dynamics in imports are exemplified by increased emissions from trade operations and a shift in demand towards cleaner and more sustainable imports due to stricter environmental regulations. Both remittance income and environmental degradation, manifested by rising energy and healthcare costs, influence household spending. Instrument overidentification issues are dismissed using the Hansen J-test and difference-in-Hansen test, which confirm the validity of the selected instruments, with P-values exceeding traditional thresholds. Additionally, as expected in the dynamic panels, the Arellano-Bond tests indicate first-order serial correlation, while the absence of second-order correlation confirms the correct specification of moment conditions. Collectively, these tests reinforce the robustness of the baseline findings, demonstrating that the asymmetric dynamics observed in CS-ARDL and NARDL estimates are genuine patterns resulting from internal interactions rather than statistical anomalies. Consequently, the policy implications derived from the models are reliable given the continuous assessment of instrument quality and the absence of higher-order autocorrelation. Therefore, it is imperative to formulate policies that consider feedback dynamics because the results demonstrate that remittances, imports, and household consumption exert complex bidirectional effects on environmental sustainability.

4.5. Policy Suggestion

Firstly, the government can implement policies that encourage environmentally friendly products and services to promote green consumerism. This can include tax rebates or subsidies for energy-efficient appliances, eco-friendly packaging, and sustainable transportation options. By encouraging green purchases, households can adopt more sustainable consumption behaviors and reduce their environmental impact. Secondly, public awareness campaigns can be launched to educate households about the environmental impact of their consumption choices and the benefits of adopting sustainable lifestyles. These campaigns can use various media, social media, and community events to disseminate information on sustainable consumption practices, recycling initiatives, and waste reduction strategies. These campaigns can drive behavioural change and promote more sustainable consumption patterns by raising awareness and fostering a sense of environmental responsibility. Third, mandatory product labelling and certification schemes can be introduced to inform consumers about the environmental attributes of products. Labels indicating energy efficiency, carbon footprint, and eco-friendly manufacturing processes can help consumers make informed choices and prioritise environmentally sustainable options. By increasing transparency and accountability, product labelling initiatives empower consumers to align their consumption decisions with their environmental values, driving demand for sustainable products and encouraging businesses to adopt greener practices. Next, waste reduction and recycling programs can be implemented at the community level to minimise the environmental impact of household consumption. These programs can include curbside recycling collection, composting initiatives, and hazardous waste disposal services. Promoting waste diversion from landfills and encouraging recycling, these programs help conserve natural resources, reduce greenhouse gas emissions, and mitigate environmental pollution. Incentivising participation through rewards or rebates can enhance program effectiveness and encourage greater household engagement in sustainable waste management practices. Finally, supporting circular economy initiatives is another way to promote sustainable consumption. Governments can fund research and development projects focused on eco-design, product refurbishment, and remanufacturing processes. By transitioning towards a circular economy model, which aims to minimize waste generation and maximize resource utilization, governments can create economic opportunities, reduce environmental degradation, and foster long-term ecological sustainability.

5. CONCLUSION AND FUTURE DIRECTION

5.1. Conclusion

This study investigates the interconnections between remittances, household consumption, imports, renewable energy, financial development, globalization, and institutional quality in influencing environmental outcomes, as measured by CO_2 emissions and ecological footprint. Employing advanced econometric techniques that address cross-sectional dependence, slope heterogeneity, nonlinearities, and endogeneity, the analysis offers comprehensive insights into both the long- and short-term dynamics across the leading remittance-receiving countries. The findings reveal that remittances consistently mitigate environmental degradation when allocated to productive and clean use. Both baseline and nonlinear estimations suggest that increased remittance inflows are linked to reductions in CO_2 emissions and the ecological footprint, although asymmetry is observed, with positive shocks exerting more substantial effects than negative shocks. This underscores the significance of directing remittance flows toward sustainable consumption and green investment. Renewable energy consumption was confirmed as a crucial mitigating factor that alleviates environmental pressures across all models. These results highlight the substitution of fossil fuel dependence with renewable energy, providing evidence of its essential role in achieving climate targets. Conversely, financial development and globalization tend to intensify environmental stress. These positive effects reflect the scale and composition of economic activities facilitated by more developed financial systems and integration into global trade, where resource-intensive production prevails in the absence of effective regulation. Institutional quality consistently emerged as a moderating factor. Strong governance, transparent regulations, and efficient institutional frameworks significantly reduce emissions and ecological footprints, counteracting the negative pressures associated with globalization and financial development. Household consumption and imports are identified as mediating channels that amplify or mitigate environmental outcomes depending on their structure and orientation.

5.2. Future Direction of the Study

The future direction of this study offers exciting possibilities for further research and analysis. There are several avenues to explore to deepen our understanding of the relationship between socioeconomic factors and environmental sustainability. Expanding the scope of the study by including additional variables and countries could provide valuable insights. Incorporating variables such as technological innovation, governance indicators, and social capital would help us understand their impact on environmental outcomes. Similarly, studying a broader range of countries, particularly those in emerging economies and developing regions, would give us a more comprehensive understanding of global environmental sustainability. Using advanced econometric techniques and methodologies could improve the accuracy and precision of the analysis. Employing state-of-the-art panel data methods, such as dynamic panel data models, spatial econometrics, and machine learning algorithms, would provide more accurate estimates and capture complex interactions among variables. Additionally, integrating qualitative methods like case studies and stakeholder interviews would give in-depth insights into the contextual factors influencing environmental outcomes.

FUNDING

This study received financial support from the Institute for Advanced Research (IAR), United International University (UIU), References No: IAR-2026-PUB-001

REFERENCES

Ahmad, M., Ul Haq, Z., Khan, Z., Khattak, S.I., Rahman, Z.U., Khan, S. (2019), Does the inflow of remittances cause environmental degradation? Empirical evidence from China. Economic Research-Ekonomska Istraživanja, 32(1), 2099-2121.

Ahmad, W., Ozturk, I., Majeed, M.T. (2022), How do remittances affect environmental sustainability in Pakistan? Evidence from NARDL approach. Energy, 243, 122726.

Ahmed, F., Kousar, S., Pervaiz, A., Ramos-Requena, J.P. (2020), Financial development, institutional quality, and environmental degradation nexus: New evidence from asymmetric ARDL co-integration approach. Sustainability, 12(18), 7812.

Akanle, O., Kayode, D., Abolade, I. (2022), Sustainable development goals (SDGs) and remittances in Africa. Cogent Social Sciences, 8(1), 2037811.

Akinlo, T. (2022), Asymmetric effect of remittances on environmental degradation in Nigeria. Chinese Journal of Urban and Environmental Studies, 10(03), 2250019.

Alibašić, H., Atkinson, C.L. (2023), Policy transfer framework in the environmental governance of non-Eu and EU member countries: A comparative analysis of Bosnia and Herzegovina and Croatia. Sustainability, 15(13), 10359.

Apergis, N., Payne, J.E. (2018), Governance, institutions and environmental performance. Energy Economics, 72, 156-170.

Arellano, M., Bond, S. (1991), Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. The Review of Economic Studies, 58(2), 277-297.

Baker, E. (2024), Ethical implications of environmental policies and practices. International Journal of Philosophy, 3(1), 37-40.

Baldé, Y. (2011), The impact of remittances and foreign aid on savings/investment in Sub-Saharan Africa. African Development Review, 23(2), 247-262.

Baloch, M.A., Öztürk, İ., Bekun, F.V., Khan, D. (2020), Modeling the dynamic linkage between financial development, energy innovation, and environmental quality: Does globalization matter? Business Strategy and the Environment, 30(1), 176-184.

Benhamou, Z.A., Cassin, L. (2021), The impact of remittances on savings, capital and economic growth in small emerging countries. Economic Modelling, 94, 789-803.

Bersvendsen, T., Ditzen, J. (2021), Testing for slope heterogeneity in Stata. The Stata Journal, 21(1), 51-80.

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

Brasseur, G., Gallardo, L. (2016), Climate services: Lessons learned and future prospects. Earth S Future, 4(3), 79-89.

Bremberg, N., Mobjörk, M., Krampe, F. (2022), Global responses to climate security: Discourses, institutions and actions. Journal of Peacebuilding and Development, 17(3), 341-356.

Charfeddine, L., Kahia, M. (2019), Impact of renewable energy consumption and financial development on CO_2 emissions and economic growth in MENA countries. Energy Policy, 132, 1181-1191.

Chishti, M.Z., Dogan, E., Zaman, U. (2023), Effects of the circular economy, environmental policy, energy transition, and geopolitical risk on sustainable electricity generation. Utilities Policy, 82, 101585.

Chudik, A., Pesaran, M.H. (2015), Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. Journal of Econometrics, 188(2), 393-420.

Das, A., Sethi, N. (2020), Effect of foreign direct investment, remittances, and foreign aid on economic growth: Evidence from two emerging South Asian economies. Journal of Public Affairs, 20(3), e2043.

Dash, R.K., Gupta, D.J., Singh, N. (2024), Remittances and environment quality: Asymmetric evidence from South Asia. Research in Globalization, 8, 100182.

De Haas, H. (2010), Migration and development: A theoretical perspective. International Migration Review, 44(1), 227-264.

Du, J., Ali, K., Alnori, F., Ullah, S. (2022), The nexus of financial development, technological innovation, institutional quality, and environmental quality: Evidence from OECD economies. Environmental Science and Pollution Research, 29(38), 58179-58200.

Du, T., Ni, J., Wang, D. (2023), Fast context-awareness encoder for LiDAR point semantic segmentation. Electronics, 12(15), 3228.

Duberry, J. (2019), Global Environmental Governance in the Information Age. London: Routledge.

Eberhardt, M., Teal, F. (2010), Productivity Analysis in Global Manufacturing Production. Economics Series Working Papers.

Elbatanony, M., Attiaoui, I., Ali, I.M.A., Nasser, N., Tarchoun, M. (2021), The environmental impact of remittance inflows in developing countries: Evidence from method of moments quantile regression. Environmental Science and Pollution Research, 28(35), 48222-48235.

Gale, F., Davison, A., Wood, G., Williams, S., Towle, N. (2015), Four impediments to embedding education for sustainability in higher education. Australian Journal of Environmental Education, 31(2), 248-263.

Hassan, M.K., Shahbaz, M., Sun, Y. (2023), Do remittances contribute to sustainable environment? Global evidence. Journal of Cleaner Production, 412, 137395.

Herwartz, H., Siedenburg, F. (2008), Homogenous panel unit root tests under cross sectional dependence: Finite sample modifications and the wild bootstrap. Computational Statistics and Data Analysis, 53(1), 137-150.

Herwartz, H., Siedenburg, F. (2019), Homogeneous panel unit root tests under cross-sectional dependence. Economics Letters, 174, 105-109.

İncesu, O., Yas, M.A. (2023), The relationship between nursing students' environmental literacy and awareness of global climate change. Public Health Nursing, 41(1), 67-76.

Islam, M.S. (2022), Do personal remittances cause environmental pollution? Evidence from the top eight remittance-receiving countries. Environmental Science and Pollution Research, 29(24), 35768-35779.

Juodis, A., Reese, S. (2022), The incidental parameters problem in testing for remaining cross-section correlation. Journal of Business and Economic Statistics, 40(3), 1191-1203.

Kibria, M.G. (2022), Environmental downfall in Bangladesh: Revealing the asymmetric effectiveness of remittance inflow in the presence of foreign aid. Environmental Science and Pollution Research, 29(1), 731-741.

Kibria, M.G. (2023), Ecological footprint in Bangladesh: Identifying the intensity of economic complexity and natural resources. Heliyon, 9(4), e14747.

Kibria, M.G., Jahan, I., Mawa, J. (2021), Asymmetric effect of financial development and energy consumption on environmental degradation in South Asia? New evidence from non-linear ARDL analysis. SN Business and Economics, 1(4), 56.

King, R., Collyer, M. (2016), Migration and development framework and its links to integration. In: Garcés-Mascareñas, B., Penninx, R., editors. Integration Processes and Policies in Europe: Contexts, Levels and Actors. Cham: Springer International Publishing. p167-188.

Le, T.H. (2022), Remittances and environmental sustainability: Evidence from developing economies. Energy Economics, 105, 105743.

Li, K., Wang, X., Musah, M., Ning, Y., Murshed, M., Alfred, M.,… & Wang, L. (2022), Have international remittance inflows degraded environmental quality? A carbon emission mitigation analysis for Ghana. Environmental Science and Pollution Research, 29(40), 60354-60370.

Liu, H., Alharthi, M., Atil, A., Zafar, M.W., Khan, I. (2022), A non-linear analysis of the impacts of natural resources and education on environmental quality: Green energy and its role in the future. Resources Policy, 79, 102940.

Liu, H., Alharthi, M., Zafar, M.W., Tahir, M.S., Asghar, M.M. (2023), Understanding the role of technology in Asian economies: The environmental impact of remittances and economic complexity. Evaluation Review, 47(6), 951-982.

López, J.A.P., Palacios, F.J.P. (2024), Effects of a project-based learning methodology on environmental awareness of secondary school students. International Journal of Instruction, 17(1), 1-22.

Luo, G.C., Luo, G.Q. (2024), Linkages between industry, agriculture, growth, renewable energy and the environment and the role of institutional quality, evidence from selected South and East Asian Economies. Energy Exploration and Exploitation, 43(1), 354-377.

Mughal, N., Arif, A., Jain, V., Chupradit, S., Shabbir, M.S., Ramos-Meza, C.S., Zhanbayev, R. (2022), The role of technological innovation in environmental pollution, energy consumption and sustainable economic growth: Evidence from South Asian economies. Energy Strategy Reviews, 39, 100745.

Musah, M. (2023), Stock market development and environmental quality in EU member countries: A dynamic heterogeneous approach. Environment, Development and Sustainability, 25(10), 11153-11187.

Nathaniel, S.P., Bekun, F.V. (2020), Renewable energy consumption and environmental sustainability in emerging economies. Environmental Science and Pollution Research, 27, 29000-29017.

Neog, Y., Yadava, A.K. (2020), Nexus among CO_2 emissions, remittances, and financial development: A NARDL approach for India. Environmental Science and Pollution Research, 27(35), 44470-44481.

Ntow-Gyamfi, M., Bokpin, G.A., Aboagye, A.Q., Ackah, C. (2020), Environmental sustainability and financial development in Africa; does institutional quality play any role? Development Studies Research, 7(1), 93-118.

Ogutu, F.A., Kimata, D., Kweyu, R. (2019), The role of environmental governance in solid waste management, policy implementation in Nairobi County. Civil and Environmental Research, 11, 49-54.

Ojeyinka, T.A., Oje, G.N. (2024), Financial Development and Environmental Sustainability in Nigeria: Does Institutional Environment Matter? Berlin: Springer Science and Business Media LLC.

Pesaran, M.H. (2004), General Diagnostic Tests for Cross-Sectional Dependence in Panels. CESifo Working Paper Series.

Porter, S., Couper, P. (2021), Autoethnographic Stories for Self and Environment: A Reflective Pedagogy to Advance "Environmental Awareness" in Student Outdoor Practitioners. Journal of Adventure Education and Outdoor Learning, 23(1), 25-37.

Powell, D. (2022), Quantile treatment effects in panel data with endogenous regressors. Journal of Econometrics, 228(2), 318-343.

Qamruzzaman, M., Karim, S., Kor, S. (2023), Does environmental degradation matter for poverty? Clarifying the nexus between FDI, environmental degradation, renewable energy, education, and poverty in Morocco and Tunisia. Environmental Science and Pollution Research, 30(18), 52872-52894.

Rahman, M.M., Hosan, S., Karmaker, S.C., Chapman, A.J., Saha, B.B. (2021), The effect of remittance on energy consumption: Panel cointegration and dynamic causality analysis for South Asian countries. Energy, 220, 119684.

Rani, T., Wang, F., Rauf, F., Ain, Q.U., Ali, H. (2023), Linking personal remittance and fossil fuels energy consumption to environmental degradation: Evidence from all SAARC countries. Environment, Development and Sustainability, 25(8), 8447-8468.

Rizk, R., Slimane, M.B. (2018), Modelling the relationship between poverty, environment, and institutions: A panel data study. Environmental Science and Pollution Research, 25(31), 31459-31473.

Ruseva, T.B., Foster, M., Arnold, G., Siddiki, S., York, A.M., Pudney, R., Chen, Z. (2019), Applying policy process theories to environmental governance research: Themes and new directions. Policy Studies Journal, 47(S1), 12317.

Russel, D., Turnpenny, J., Jordan, A. (2018), Mainstreaming the environment through appraisal: Integrative governance or logics of disintegration? Environment and Planning C Politics and Space, 36(8), 1355-1370.

Serfraz, A., Qamruzzaman, M., Karim, S. (2023), Revisiting the nexus between economic policy uncertainty, financial development, and FDI inflows in Pakistan during Covid-19: Does clean energy matter? International Journal of Energy Economics and Policy, 13(4), 91-101.

Shahbaz, M., Nasreen, S., Ling, C.H., Sbia, R. (2018), Does economic growth and globalization affect CO_2 emissions? Evidence from emerging economies. International Journal of Environmental Research and Public Health, 15(11), 2235.

Shin, Y., Yu, B., Greenwood-Nimmo, M. (2014), Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In: Festschrift in Honor of Peter Schmidt. Berlin: Springer. p281-314.

Sobiech, I. (2019), Remittances, finance and growth: Does financial development foster the impact of remittances on economic growth? World Development, 113, 44-59.

Tan, Y., Qamruzzaman, M., Karim, S. (2023), An investigation of financial openness, trade openness, gross capital formation, urbanization, financial development, education and energy nexus in BRI: Evidence from the symmetric and asymmetric framework. PLoS One, 18(12), e0290121.

Tebourbi, I., Thi Truc Nguyen, A., Yuan, S.F., Huang, C.Y. (2023), How do social and economic factors affect carbon emissions? New evidence from five ASEAN developing countries. Economic Research-Ekonomska Istraživanja, 36(1), 2120038.

Westerlund, J., Edgerton, D.L. (2007), A panel bootstrap cointegration test. Economics Letters, 97(3), 185-190.

Westerlund, J., Edgerton, D.L. (2008), A simple test for cointegration in dependent panels with structural breaks. Oxford Bulletin of Economics and Statistics, 70(5), 665-704.

Williams, K. (2021), Do remittances condition the relationship between trade and government consumption? Applied Economics Letters,

28(18), 1571-1577.
Yang, B., Jahanger, A., Ali, M. (2021), Remittance inflows affect the ecological footprint in BICS countries: do technological innovation and financial development matter? Environmental Science and Pollution Research, 28, 23482-23500.
Yasmeen, H., Wang, Y., Zameer, H., Ismail, H. (2019), Modeling the role of government, firm, and civil society for environmental sustainability. International Journal of Agricultural and Environmental Information Systems, 10(2), 82-97.
Zaman, U., Chishti, M.Z., Hameed, T., Akhtar, M.S. (2023), Exploring the nexus between green innovations and green growth in G-7 economies: Evidence from wavelet quantile correlation and continuous wavelet transform causality methods. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-023-28982-z
Zhang, J., Ullah, S., Khan, K. (2023), The prominence of fossil energy resources in ecological sustainability of BRICS: The key role of institutional worth. Frontiers in Environmental Science, 10, 1084314.
Zhao, L., Qamruzzaman, M. (2022), Do urbanization, remittances, and globalization matter for energy consumption in belt and road countries: Evidence from renewable and non-renewable energy consumption. Frontiers in Environmental Science, 10, 930728.
Zhu, S. (2023), How international organizations influence state behaviour: A comparative study of environmental governance. Journal of Education Humanities and Social Sciences, 23, 563-569.