Applied Environmental Research
- RESEARCH FOR SUSTAINABLE PLANET -

Research Article

The Role of Remittances in Economic Growth and Environmental Sustainability: A Cross-country Analysis

Bishnu Bahadur Khatri[1], Omkar Poudel[2,*], Pradeep Acharya[3]

[1] *Central Department of Rural Development, Tribhuvan University (TU), Nepal*
[2] *Birendra Multiple Campus, Tribhuvan University, Nepal*
[3] *Tribhuvan University, Kathmandu, Nepal*

*Corresponding Email: omkar.poudel@bimc.tu.edu.np

Abstract

Although remittances significantly influence economic stability, their role in sustainable growth and environmental impact remains uncertain. While these financial inflows enhance household welfare, their effects on gross domestic product (GDP), carbon emissions, and trade openness require further exploration. This study investigates the economic and environmental linkages of remittances in India, Mexico, China, the Philippines, and Pakistan, the top five remittance-receiving countries. Using panel data analysis, this study employs Dumitrescu Hurlin causality tests and dynamic ordinary least squares (DOLS) to assess the long-term and causal relationships between urbanization, trade openness, GDP per capita, carbon emissions, and remittances. Data from the World Bank for the five largest remittance-receiving countries are used to ensure robust empirical analysis. The findings indicate that remittances do not directly drive GDP or emissions but that urbanization and trade openness significantly shape economic and environmental outcomes. This study supports the environmental Kuznets curve (EKC) hypothesis and confirms that carbon emissions influence remittance flows, which aligns with the environmental migration hypothesis. This study highlights the importance of remittance-backed investments in renewable energy, green infrastructure, and financial inclusion programs. Policymakers should create incentives for migrants to channel remittances into productive sectors rather than pure consumption. Trade openness has emerged as a key driver of emissions, necessitating sustainable trade policies that integrate environmental regulations. The study underscores the need for targeted policies that enhance the productive use of remittances while mitigating environmental risk.

ARTICLE HISTORY

Received: 22 Oct. 2024
Accepted: 20 Apr. 2025
Published: 18 May 2025

KEYWORDS

Remittances;
GDP per capita;
Carbon emission;
Environmental Kuznets curve;
Trade openness;
Urbanization

Introduction

The role of remittances in shaping economic growth and environmental sustainability has garnered significant attention in the contemporary economic literature. As globalization intensifies and international migration intensifies, remittance flows have emerged as crucial sources of external financing for many developing economies [1]. These financial inflows contribute to household consumption, investment, and poverty alleviation, thus fostering economic growth [2]. However, the broader implications of remittances extend beyond economic expansion, particularly in terms of their impact on environmental sustainability. While remittances can enhance renewable energy adoption and environmental awareness, they may also contribute to environmental degradation through increased consumption and energy demand [3]. This paradox presents an intriguing research venue that necessitates a comprehensive cross-country analysis.

Remittances are financial transfers sent by migrants to their home countries through formal (banks, money transfer operators) or informal channels. They serve as a critical financial inflow, influencing household conumption, investment, and macroeconomic stability. To

https://doi.org/10.35762/AER.2025012

assess the significance of remittances, Table 1 compares remittance inflows as a percentage of gross domestic product (GDP) and tax revenue across the selected countries:

Table 1 Remittance inflows as a percentage of GDP and tax revenue

Country	Remittances (% of GDP)	Tax revenue (% of GDP)
India	3.2	16.5
Mexico	4.1	15.8
China	0.5	19.7
Philippines	9.7	14.3
Pakistan	8.5	12.2

Source: [29]

Table 1 demonstrates the economic importance of remittances, particularly in countries such as the Philippines and Pakistan, where they constitute a substantial share of GDP. The economic significance of remittances is well documented, particularly in developing nations, where they constitute a substantial portion of GDP [4]. Studies suggest that remittances positively influence investment in human capital, infrastructure, and entrepreneurship, driving long-term economic stability [5]. Nonetheless, their role in environmental outcomes remains ambiguous. On the one hand, remittance-receiving households may allocate funds to cleaner energy sources and sustainable practices [6]. On the other hand, increased disposable income can lead to higher carbon emissions due to greater consumption of fossil fuels and energy-intensive goods [7].

Recent empirical investigations highlight the complex interplay between remittances, energy consumption, and carbon emissions. Several studies have underscored the asymmetric impact of remittances on environmental degradation, noting that financial inflows can either exacerbate or mitigate the carbon footprint, depending on institutional quality and energy policies [8]. Furthermore, urbanization and globalization serve as key mediators in this relationship, influencing the extent to which remittances translate into environmental improvements or degradation [9]. Given these multidimensional dynamics, a nuanced understanding of remittance-driven economic growth and environmental sustainability is essential for policymakers striving to balance financial inflows with ecological preservation.

This study aims to investigate the dual role of remittances in economic growth and environmental sustainability through a cross-country analysis. By employing robust panel data methodologies, we assess how remittances influence economic expansion and environmental quality across different economic and institutional contexts. The findings contribute to the ongoing discourse on sustainable development by offering policy recommendations that optimize the benefits of remittance inflows while mitigating their environmental costs.

Literature review

The theoretical and empirical literature has reviewed the role of remittances in economic growth and environmental sustainability below.

1) Theoretical review

Remittances play a crucial role in economic development, serving as a vital source of external financing, particularly in developing economies. Bhattacharya et al. [10] emphasized that remittance inflows contribute to financial sector growth by increasing credit availability and supporting entrepreneurship. Furthermore, Nguyen and Vu [11] argued that remittances improve household welfare by increasing access to education and healthcare, fostering long-term economic stability. However, excessive reliance on remittances may reduce labor force participation and productivity, leading to a dependency effect [12]. Additionally, Ali and Ismail [4] highlight the potential adverse effects of remittances on macroeconomic performance, including inflationary pressures and exchange rate volatility, which may hinder sustainable economic growth.

In addition to their economic significance, remittances also influence environmental sustainability, although the effects remain highly contextual. Wang et al. [13] reported that remittance inflows increase carbon emissions in remittance-receiving countries because of increased consumption of fossil fuel-based energy. Similarly, Islam and Alhamad [14] argued that remittances indirectly drive environmental degradation by fueling urban expansion and industrialization. However, other studies present a contrasting view. Chen et al. [15] suggested that remittance-receiving households in developing countries allocate a portion of their income toward cleaner energy sources, reducing environmental harm in the long run. This dichotomy aligns with the environmental Kuznets curve (EKC) hypothesis, which posits that economic growth initially worsens environmental quality before leading to sustainability through technological improvements and policy interventions [16].

The interplay between remittances, globalization, and financial development further complicates their environmental impact. Rehman et al. [17] highlight that when coupled with financial globalization, remittances may either exacerbate or mitigate carbon emissions, depending on how funds are utilized. Similarly, Sadiq et al. [18] reported that remittance-induced economic expansion in South Asian countries has a mixed effect on environmental sustainability, with improvements observed only in nations that actively invest in renewable energy. This variation underscores the need for strong regulatory frameworks and targeted policies to optimize the benefits of remittance inflows while minimizing their ecological costs [19].

Given these complexities, recent studies call for policy interventions that channel remittance inflows toward sustainable development. Umair et al. [20] emphasized the importance of green financial policies that encourage remittance recipients to invest in renewable energy projects. Additionally, Hasanov et al. [21] suggested that institutional quality plays a key role in determining whether remittance inflows contribute to environmental sustainability or degradation. These insights highlight the necessity of an integrated approach that aligns financial inflows with long-term ecological goals, ensuring that remittances serve as a catalyst for both economic and environmental progress.

2) Empirical review

The relationship between remittances and economic growth has been extensively examined in the economic literature. Several studies emphasize the positive role of remittances in fostering economic development by providing financial resources that boost consumption, investment, and human capital accumulation. For instance, Ratha et al. [1] highlight how remittances serve as a stable source of external financing, reducing economic volatility and promoting macroeconomic stability. Similarly, studies by Askarov and Doucouliagos [22] and Chhetri et al. [23] demonstrate that remittances contribute significantly to GDP growth in developing nations by financing education, healthcare, and entrepreneurial activities.

While remittances play a crucial role in economic development, their impact on growth is not uniformly positive. Excessive reliance on remittance inflows can create economic distortions, reducing incentives for labor force participation and productive investments [24]. Moreover, remittances can contribute to macroeconomic challenges such as currency appreciation, which may undermine export competitiveness, leading to a phenomenon similar to the "Dutch disease" [4, 16]. Additionally, studies suggest that remittances influence environmental sustainability, as they can drive higher energy consumption and carbon emissions in recipient economies [7, 8]. Therefore, while remittances provide economic benefits, their broader implications necessitate careful policy considerations.

The environmental implications of remittances have garnered increasing attention in recent years. Several studies have examined how remittance-induced economic activities influence carbon emissions and environmental sustainability. Khan et al. [25] and Islam [7] argued that increased disposable income from remittances often translates into increased consumption of energy-intensive goods and fossil fuels, leading to increased carbon emissions. Conversely, other scholars suggest that remittance flows can enhance environmental sustainability by facilitating investments in renewable energy and environmentally friendly technologies [26]. This divergence in findings suggests that the impact of remittances on environmental sustainability is context dependent and influenced by institutional frameworks, energy policies, and socioeconomic structures.

Furthermore, empirical studies indicate that the interplay between remittances, globalization, and urbanization significantly shapes environmental outcomes. Neog and Yadava [27] highlighted that remittances can exacerbate environmental degradation in rapidly urbanizing economies through increased energy consumption and infrastructure expansion. On the other hand, Abdul et al. [28] suggested that when coupled with strong governance and environmental policies, remittances can serve as a catalyst for sustainable development by promoting green investments and energy efficiency.

While the literature provides valuable insights into the economic and environmental effects of remittances, there remains a lack of consensus regarding their overall impact. The heterogeneity in findings underscores the need for further research that considers cross-country variations, institutional factors, and policy frameworks. This study aims to bridge this gap by conducting a comprehensive analysis of the dual role of remittances in economic growth and environmental sustainability, contributing to the broader discourse on sustainable development.

This study examines the relationship between carbon emissions and remittances in the five largest remittance-receiving countries. It investigates how remittance inflows drive economic activities that may, in turn, influence carbon emissions. Additionally, this study highlights the importance of policy measures that align remittance utilization with environmental sustainability. To achieve these objectives, the following hypotheses are formulated and analyzed:

Economic impact of remittances

H1: Personal remittances have a significant positive effect on GDP per capita in remittance-receiving countries.

H2: Trade openness significantly enhances GDP per capita by facilitating economic expansion.

H3: Urban population growth is positively associated with GDP per capita, reflecting the role of urbanization in economic development.

H4: Population growth has a significant effect on GDP per capita, influencing labor market dynamics and economic productivity.

Environmental impact of remittances

H5: Personal remittances significantly increase carbon dioxide emissions by driving higher energy consumption and industrial activity.

H6: GDP per capita is positively associated with carbon dioxide emissions, supporting the EKC hypothesis.

H7: Trade openness significantly contributes to carbon dioxide emissions through increased production and transportation activities.

H8: Urban population growth significantly impacts carbon dioxide emissions, reflecting the environmental consequences of rapid urbanization.

Materials and methods

This study employs a balanced panel dataset covering the period 1990–2023 to examine the long-run relationship between carbon emissions and remittances. The dataset includes five major remittance-receiving economies, India, Mexico, China, the Philippines, and Pakistan, which are selected on the basis of their substantial remittance inflows and economic diversity.

1) Data and variables

Data for key variables were sourced from the World Development Indicators (WDI) database [29] to ensure consistency in definitions and measurements across countries.

The dependent variable in this study is carbon dioxide emissions, measured in metric tons per capita. The key independent variable is personal remittances (US$). Additional control variables include GDP per capita (constant 2015 US dollars), the urban population (percentage of the total population), population growth (annual percentage), and trade (percentage of GDP). These variables were selected on the basis of their relevance in explaining the environmental and economic dynamics associated with remittance inflows. Table 2 presents the variables, their symbols, units, and data sources.

Table 2 Variables, units and data used in the research

Variable names	Units	Sources
Carbon dioxide emission	Metric tons per capita	[29]
Personal remittances	US$	[29]
GDP per capita	constant 2015 US$	[29]
Urban population	% of the total population	[29]
Population growth	annual %	[29]
Trade	% of GDP	[29]

2) Economic methodology

To estimate the long-term relationship between remittances and carbon emissions, this study applies the panel dynamic ordinary least squares (DOLS) estimator. DOLS is widely used for cointegrated panel data, as it accounts for endogeneity and serial correlation by incorporating leads and lags of explanatory variables [30]. The DOLS estimator is particularly effective in providing unbiased and efficient long-run coefficient estimates in small sample settings.

3) Unit root tests

Before the model is estimated, panel unit root tests are conducted to check the stationarity properties of the variables. The study employs three standard tests:

The *Levin, Lin & Chu (LLC) test* assumes a common unit root process.

The im, Pesaran & Shin (IPS) test allows for individual unit root processes.

Maddala and Wu–ADF test **–** a nonparametric test based on augmented Dickey–Fuller (ADF) principles.

PP - Fisher chi-square test **–** a nonparametric test based on the Phillips–Perron (PP) methodology, which accounts for heteroskedasticity and serial correlation in panel data.

These tests collectively help determine whether the variables exhibit stationarity, ensuring reliable econometric analysis in the study.

4) Panel cointegration analysis

If all the variables are integrated in the same order, panel cointegration tests are performed to assess the existence of a long-run equilibrium relationship. The study utilizes:

Kao (1999) tests residual-based approaches to detect cointegration.

Johansen-Fisher test **–** a likelihood-based approach evaluating the null hypothesis of no cointegration.

5) DOLS model specification

After confirming cointegration, the following DOLS model is estimated as shown in Eq.1.

In this model, "i" stands for the country, and "t" represents the time period. This setup helps to estimate the long-term coefficients more accurately. In accordance with Grossman & Krueger (1994), the model also includes the nonlinear link between GDP and carbon emissions, as shown in Eq.2.

By incorporating leads and lags of the explanatory variables, this estimator effectively addresses issues related to small sample bias, endogeneity, and autocorrelation [30]. To further validate the findings, the Dumitrescu–Hurlin (DH) panel causality test is applied to investigate the direction of causality between remittances and carbon emissions across countries.

$$(\text{Carbon dioxide emission})_{it} = \beta_0+\beta_1(\text{Personal remittances})_{it}+\beta_2(\text{GDP per capita})_{it}+\beta_3(\text{Urban population})_{it} +\beta_4(\text{Population growth})_{it}+\beta_5(\text{Trade})_{it}+\epsilon_{it} \quad \text{(Eq.1)}$$

$$\text{Ln}(\text{Carbon dioxide emission}_{it}) = \beta_0+ \beta_1\text{L}(\text{Carbon dioxide emission}_{it})+\beta_2\text{L}(\text{Personal remittances}_{it}) +\beta_3\text{L}(\text{GDP per capita})_{it}+\beta_4\text{L}(\text{Urban population}_{it})+\beta_5\text{L}(\text{Population growth}_{it}) +\beta_6\text{L}(\text{Trade}_{it}) + \alpha i + \epsilon_{it} \quad \text{(Eq.2)}$$

where

Ln(Carbon dioxide emission$_{it}$) = Natural logarithm of carbon dioxide emissions for the ith country at time t.
L(Carbon dioxide emission$_{it}$) = The lagged value of the ith country's Carbon dioxide emissions at time t.
L(Personal remittances$_{it}$) = The lagged value of a variable remittance for the ith country at time t.
L(GDP per capita$_{it}$) = The lagged value of GDP per capita for the ith country at time t.
L(Urban population$_{it}$)= The lagged value of the urban population for the ith country at time t.
L(Population ggrowth$_{it}$)= The lagged value of population growth for the ith country at time t.
L(Trade$_{it}$) = The lagged value of trade openness for the ith country at time t.
α_i = ith country's unit-specific fixed effect
ϵit = error term
β_i = coefficients

Results

1) Descriptive statistics

The summary statistics provide insights into the distribution, central tendency, and variability of the key variables. This information is crucial for understanding data patterns before proceeding with econometric modeling [31].

Table 3 shows the descriptive statistics of the variables used. The mean values indicate the central tendency of each variable, with Ln(Personal remittances) showing a high average value (23.0752), reinforcing its significant role in recipient economies. Ln(GDP per capita) (7.8334) suggests moderate income levels, whereas Ln(Carbon dioxide emission) (0.5583) implies variations in environmental impact across the dataset.

The standard deviation values highlight the degree of dispersion, with Ln(Carbon dioxide emission) (0.8166) exhibiting considerable variation, likely influenced by differences in energy policies and industrial activities across countries. Ln(Trade) (0.3927) and Ln(Urban population) (0.3515) show relatively lower dispersion, indicating stable trade patterns and urbanization trends.

The skewness values reflect the distribution asymmetry. Ln(Personal Remittances) (-0.6149) is negatively skewed, indicating that most remittance flows are concentrated below the mean, potentially indicating reliance on a few high remittance-receiving countries. Conversely, Ln(Carbon dioxide emission) (0.4592) is positively skewed, suggesting that emissions levels are higher for certain countries, likely due to differences in industrialization and energy sources.

Kurtosis measures the peakness of the distribution. With values of mostly approximately 2, the variables exhibit near-normal distributions, although Ln(GDP per capita) (1.7951) and Ln(Carbon dioxide emission) (1.8148) suggest a slightly flatter distribution, indicating variations in economic development and emission patterns. These insights are valuable for policymakers aiming to balance economic growth with sustainability, ensuring that remittance inflows contribute to long-term development without exacerbating environmental degradation.

2) Correlation analysis

Correlation analysis provides insights into the strength and direction of relationships between key economic and environmental variables [32].

Table 4 presents the results of the correlation analysis of the variables used. Ln(GDP per capita) is strongly positively correlated with Ln(Carbon dioxide emission) (0.84), indicating that greater economic growth is associated with greater carbon emissions, supporting the EKC hypothesis. Similarly, Ln(Urban population) (0.66) shows a strong correlation with emissions, reflecting the role of urbanization in increasing energy demand and environmental degradation.

Remittances show a weak positive correlation with carbon emissions (0.19), suggesting that while remittance inflows may contribute to higher energy consumption, their impact on emissions is less direct than that of GDP growth and urbanization. The moderate correlation between Ln(Personal remittances) and Ln(GDP per capita) (0.33) suggests that remittances play a role in boosting economic output, although other factors likely mediate this relationship.

Trade openness (Ln(Trade) (0.26)) has a relatively weak positive correlation with emissions, implying that international trade may not be a primary driver of environmental degradation in remittance-receiving countries. Conversely, population growth (-0.79) is strongly negatively correlated with Ln(Carbon dioxide emission), suggesting that in economies with higher population growth, per capita emissions might be lower because of energy use efficiency or economic structures that do not rely heavily on carbon-intensive industries.

These findings emphasize the complex dynamics among remittances, economic expansion, and environmental sustainability. Policymakers should consider these interactions when designing strategies to leverage remittance inflows for sustainable growth while mitigating their potential environmental costs.

3) Trends in economic and environmental variables

Analyzing trends in economic and environmental variables provides valuable insights into the long-term dynamics of remittances, economic growth, and sustainability.

Figure 1 depicts the trends in the variables used. The economic and environmental trends across countries reveal distinct patterns in growth and sustainability. In India, a steady increase in Ln(GDP per capita) is accompanied by rising Ln(Carbon dioxide emission), suggesting that economic expansion is closely tied to energy consumption. Similarly, China's sharp rise in Ln(Urban population) correlates with increasing emissions, reinforcing the environmental impact of rapid urbanization. The rising Ln(Trade) trend further underscores the country's reliance on international commerce as a key economic driver. Moreover, in Mexico, stable growth in Ln(Personal remittances) suggests resilience in remittance inflows, although fluctuations in Ln(Trade) and Ln(Carbon dioxide emission) reflect changes in trade policies and industrial activity.

In contrast, the Philippines shows a stable trend in Ln(Personal remittances), indicating a consistent reliance on external financial inflows. However, the lack of significant growth in Ln(GDP per capita) suggests that remittances alone may not be sufficient to drive sustainable economic expansion. Similarly, Pakistan's rising Ln(Carbon dioxide emission) signals growing environmental challenges linked to economic activities. At the same time, increasing Ln(Personal remittances) highlights the country's dependence on foreign remittances as a crucial economic pillar, although their long-term contribution to sustainable development remains uncertain.

4) Correlation analysis

Unit root tests are employed to determine the stationarity of variables, ensuring the validity of long-run relationships in econometric modeling [33].

Table 5 shows the results of panel unit root testing. The Levin, Lin & Chu (LLC) test and Im, Pesaran & Shin (IPS) test yield mixed stationarity results across variables. Ln(Carbon dioxide emission) is found to be nonstationary at levels but attains stationarity after first differencing, as evidenced by significant negative values in the first-difference row. Similarly, Ln(Personal remittances) and Ln(GDP per capita) exhibit unit roots at levels but become stationary in first differences, suggesting long-run integration.

Table 3 Descriptive statistics of the variables used

Statistics	Ln (Carbon dioxide emission)	Ln (Personal remittances)	Ln (GDP per capita)	Ln (Urban population)	Ln (Trade)	Population growth
Mean	0.5583	23.0752	7.8334	3.7750	3.7651	1.5584
Median	0.2839	23.3940	7.5433	3.7961	3.7829	1.4917
Maximum	2.2406	25.5068	9.4072	4.4016	4.4817	3.3430
Minimum	-0.5710	19.0933	6.2765	3.2405	2.7412	-0.1038
Std. Dev.	0.8166	1.3501	0.9142	0.3515	0.3927	0.7067
Skewness	0.4592	-0.6149	0.3563	0.4375	-0.1481	0.1350
Kurtosis	1.8148	2.7946	1.7951	1.9666	2.3488	2.5211
Observations	170	170	170	170	170	170

Table 4 Correlation analysis of the variables used

Correlation	Ln (Carbon dioxide emission)	Ln (Personal remittances)	Ln (GDP per capita)	Ln (Urban population)	Ln (Trade)	Population growth
Ln(Carbon dioxide emission)	1.00	0.19	0.84	0.66	0.26	-0.79
Ln(Personal remittances)	0.19	1.00	0.33	0.30	0.40	-0.43
Ln(GDP per capita)	0.84	0.33	1.00	0.95	0.52	-0.58
Ln(Urban population)	0.66	0.30	0.95	1.00	0.58	-0.36
Ln(Trade)	0.26	0.40	0.52	0.58	1.00	-0.27
Population growth	-0.79	-0.43	-0.58	-0.36	-0.27	1.00

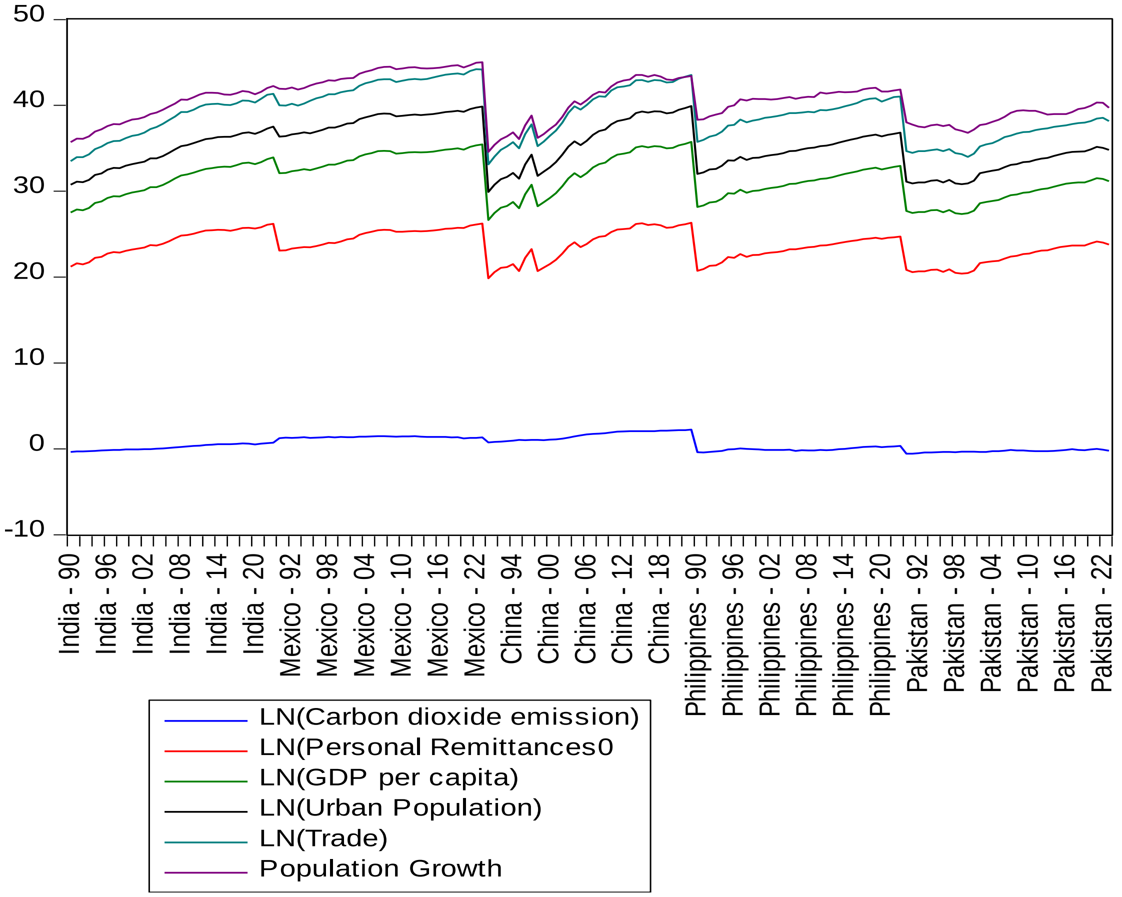

Figure 1 Trends in the variables used.

Table 5 Results of panel unit root testing

Variables	Deterministic	Levin, Lin & Chu t*	Im, Pesaran and Shin W-stat	ADF - Fisher Chi-square	PP - Fisher Chi-square
Ln(Carbon dioxide emission)	Intercept	-0.5789	0.7712	6.8414	7.4125
	Intercept & trend	0.3607	0.4150	8.4042	3.4738
D(Ln(Carbon dioxide emission))	Intercept	-2.4312***	-4.4234***	39.8755***	78.4849***
	Intercept & trend	-1.3981*	-3.2136***	29.3445***	301.4590***
Ln(Personal remittances)	Intercept	-4.0817***	-1.0159	18.8655**	42.9185***
	Intercept & trend	-0.4865	0.2816	7.7868	10.4907
D(Ln(Personal remittances))	Intercept	-1.5708*	-6.1350***	56.6068***	113.8310***
	Intercept & trend	-0.2855	-5.9564***	53.0050***	331.4100***
Ln(GDP per capita)	Intercept	-2.1511**	2.0472	7.2502	7.4873
	Intercept & trend	-0.0480	-0.1116	10.8694	12.0579
D(Ln(GDP per capita))	Intercept	-3.7459***	-5.1125***	47.9399***	93.5174***
	Intercept & trend	-3.5815***	-4.2330***	37.0908***	209.9690***
Ln(Urban population)	Intercept	2.4146	4.5123	3.2919	24.2978***
	Intercept & trend	-0.7628	1.3044	7.2339	10.6631
D(Ln(Urban population))	Intercept	0.1049	0.8829	8.3066	5.1583
	Intercept & trend	-0.0877	0.3973	10.0071	5.6546
Ln(Trade)	Intercept	-2.2325**	-1.2447	13.3463	12.8929
	Intercept & trend	-0.8302	-0.4608	13.4948	7.4106
D(Ln(Trade))	Intercept	-6.4249***	-5.7643***	51.6083***	81.8124***
	Intercept & trend	-5.9924***	-4.8220***	40.2649***	71.9904***
Population growth	Intercept	-0.3576	1.8007	3.3465	1.9038
	Intercept & trend	-0.7034	-2.0019**	19.6640**	6.6930
D(Population growth)	Intercept	-2.5277***	-5.9826***	54.0739***	29.0324***
	Intercept & trend	-1.3694*	-4.3845***	37.0085***	18.5427**

The ADF-Fisher chi-square test and PP-Fisher chi-square test corroborate these findings, with higher values in the first-difference rows indicating the rejection of the null hypothesis of unit roots, thereby affirming stationarity. For instance, D(Ln(Carbon dioxide emission)) and D(Ln(Personal remittances)) demonstrate significant test statistics, confirming that these variables follow an integrated process. These results justify the application of cointegration techniques to examine long-term relationships between remittances, economic growth, and environmental sustainability.

From a country-specific perspective, India and China exhibit stronger persistence in carbon emissions, as indicated by weaker stationarity results at levels. This persistence underscores the need for stricter environmental regulations and sustainable energy policies in these economies. On the other hand, Mexico and the Philippines present more stable stationarity patterns in remittance flows, suggesting that more predictable financial inflows can be effectively leveraged for economic development. In contrast, Pakistan presents fluctuating stationarity properties in both economic and environmental variables, reflecting macroeconomic volatility and structural inefficiencies. These findings highlight the necessity of country-specific policy measures to ensure that remittance inflows contribute to long-term economic growth while mitigating environmental externalities.

5) Cointegration

Cointegration analysis is essential for determining the presence of a long-term equilibrium relationship between remittances, economic growth, and environmental sustainability [34].

Table 6 shows that the results from the Kao residual cointegration test indicate that the ADF t statistic (-3.296569) is highly significant, with a p value of 0.0005, strongly rejecting the null hypothesis of no cointegration. This suggests that despite short-term fluctuations, the variables exhibit a stable long-term relationship.

The residual variance (0.001474) and HAC variance (0.001916) further support the robustness of the estimated cointegration relationship. These findings imply that policies aimed at leveraging remittances for economic growth must also consider their long-term effects on environmental sustainability. From a country-specific perspective, the presence of cointegration suggests that in economies such as India and China, where emissions are persistent, integrating renewable energy investments with remittance utilization could enhance sustainable growth. With more stable financial inflows, Mexico and the Philippines can adopt long-term strategies to channel remittances into productive sectors. In contrast, Pakistan's macroeconomic volatility necessitates policy interventions that stabilize both financial and environmental factors over the long run.

These results underscore the importance of long-term policy frameworks that optimize the developmental benefits of remittances while mitigating their environmental consequences.

Table 6 Results of the Kao residual cointegration test

Statistics	t-Statistic	Prob.
ADF	-3.296569	0.000
Residual variance	0.001474	
HAC variance	0.001916	

Table 7 shows the results of the Johansen Fisher panel cointegration test. The Johansen Fisher panel cointegration test is applied to assess the presence of multiple long-run equilibrium relationships among remittances, economic growth, and environmental sustainability. The results in Table 6 indicate strong evidence of cointegration, as shown by the high Fisher statistics and low p values (0.0000) for the first three cointegration equations. This implies that despite short-term fluctuations, these variables share a stable long-term relationship, justifying the use of Panel DOLS as a suitable estimation method to obtain unbiased and efficient long-run coefficient estimates.

From an economic perspective, the presence of multiple cointegrating relationships suggests that remittances play a significant role in shaping both economic expansion and environmental outcomes. In India and China, where economic growth and carbon emissions are strongly linked, these results reinforce the need for policies that integrate remittance inflows into sustainable energy investments to mitigate environmental degradation. In Mexico and the Philippines, where financial inflows from remittances remain stable, cointegration suggests that remittances can be effectively leveraged for long-term capital formation and economic diversification. Moreover, Pakistan's mixed results indicate structural volatility, highlighting the need for macroeconomic stabilization policies to ensure that remittances contribute to both financial and environmental sustainability.

The decreasing Fisher statistics and increasing p values beyond the third cointegration equation suggest diminishing long-term interdependencies among additional variables. This implies that while remittances, economic growth, and carbon emissions share a robust long-run equilibrium, the influence of additional factors such as trade and population growth may weaken over time. These findings emphasize the importance of context-specific policies that balance remittance-driven economic benefits with environmental sustainability measures, ensuring that financial inflows do not exacerbate ecological degradation in the long run.

Table 8 shows the results from the Panel DOLS estimation and provides valuable insights into the long-run relationships among remittances, economic growth, and environmental sustainability. The coefficient for Ln(Personal remittances) (0.038843) is positive but statistically insignificant (p = 0.1125), suggesting that while remittances may contribute to economic expansion, their direct impact is not robust across the sample. This aligns with the argument that remittances primarily support household consumption rather than long-term productive investments [11]. In contrast, Ln(GDP per capita) (0.990126, p = 0.0000) is highly significant, indicating that economic growth is a primary driver of long-term environmental and economic dynamics. The nearly unitary coefficient suggests that per capita GDP and carbon emissions move proportionally in the long run, which is consistent with the EKC hypothesis, where economic growth initially leads to environmental degradation before transitioning to sustainability [16].

The negative and statistically significant coefficient for Ln(Urban Population) (-1.169312, p = 0.0108) indicates that urbanization has an inverse relationship with carbon emissions in the long run. This result challenges conventional expectations that urbanization leads to higher emissions due to increased energy consumption and infrastructure expansion [25]. One possible explanation is that urbanization in certain economies facilitates access to cleaner technologies and energy-efficient infrastructure, mitigating environmental damage. Moreover, Ln(Trade) (0.077203, p = 0.1678) and population growth (0.053021, p = 0.2349) are statistically insignificant, implying that their long-term effects on carbon emissions and economic growth may not be substantial. This suggests that while trade and population growth contribute to short-term fluctuations, their long-term influence is mediated by factors such as institutional quality, technological advancements, and environmental policies [17].

The high R-squared value (0.998468) and adjusted R-squared value (0.996631) indicate that the model explains almost all the variation in the dependent variable, confirming the robustness of the estimation. However, such a high R-squared also raises concerns about potential overfitting or omitted variable bias. The small standard error of regression (0.047121) and low sum of squared residuals (0.155426) further validate the model's efficiency. From a policy perspective, these findings highlight the need for remittance-receiving economies to enhance financial mechanisms that channel remittance inflows into productive sectors. Moreover, the inverse relationship between urbanization and emissions suggests that sustainable urban planning and green technology adoption can help reconcile economic growth with environmental sustainability.

Table 9 shows the Dumitrescu Hurlin panel causality test, which provides key insights into the relationships among remittances, economic growth, environmental sustainability, and urbanization. A significant unidirectional causality from carbon emissions to remittances (W-Stat: 6.32665, p = 7. E-05) suggests that worsening environmental conditions drive migration, leading to increased remittance inflows. This aligns with the theory of environmental migration, where individuals seek better economic opportunities abroad because of environmental stress in their home countries. However, the absence of causality in the opposite direction (p = 0.2321) contradicts the common argument that remittances drive carbon emissions. This suggests that while remittance inflows increase household consumption, their direct contribution to environmental degradation may be limited in the short run, potentially due to varying consumption patterns across countries.

Strong bidirectional causality between GDP per capita and remittances (p = 0.0415 for remittances causing GDP per capita, and p = 0.0923 for GDP per capita causing remittances) highlights a self-reinforcing economic cycle. This suggests that remittances contribute to GDP growth, which in turn increases migration potential and future remittance inflows. Similarly, a significant relationship between GDP per capita and urbanization (p = 7. E-08 for urbanization causing GDP, and p = 0.0046 for GDP causing urbanization) reinforces the role of structural transformation. This means that economic growth fuels urban expansion through industrialization, whereas urbanization, in turn, drives further economic development. The absence of strong causality between urbanization and remittances (p = 0.7653) indicates that urban population growth alone does not significantly influence remittance inflows, suggesting that migration decisions are more complex and influenced by broader economic conditions than just urban expansion.

Table 7 Results of the Johansen Fisher panel cointegration test

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	150.7	0.0000	75.69	0.0000
At most 1	86.68	0.0000	42.72	0.0000
At most 2	51.00	0.0000	30.35	0.0008
At most 3	28.03	0.0018	18.95	0.0410
At most 4	17.43	0.0655	15.72	0.1080
At most 5	13.75	0.1845	13.75	0.1845

Table 8 Results of Panel DOLS (Pooled estimation)

Variables	Coefficient	Std. Error	t-Statistic	Prob.
Ln(Personal remittances)	0.038843	0.024165	1.607433	0.1125
Ln(GDP per capita)	0.990126	0.161469	6.131992	0.0000
Ln(Urban population)	-1.169312	0.446570	-2.618433	0.0108
Ln(Trade)	0.077203	0.055393	1.393725	0.1678
Population growth	0.053021	0.044249	1.198249	0.2349
R-squared	0.998468	Mean dependent var		0.574321
Adjusted R-squared	0.996631	S.D. dependent var		0.811788
S.E. of regression	0.047121	Sum squared resid		0.155426
Long-run variance	0.001393			

Table 9 Pairwise Dumitrescu Hurlin panel causality tests

Null Hypothesis	W-Stat.	Zbar-Stat.	Prob.
Ln(Personal remittances) →Ln(Carbon dioxide emission)	3.41061	1.19491	0.2321
Ln(Carbon dioxide emission)→Ln(Personal remittances)	6.32665	3.98108	7.E-05
Ln(GDP per capita) →Ln(Carbon dioxide emission)	3.76814	1.53651	0.1244
Ln(Carbon dioxide emission) →Ln(GDP per capita)	4.18571	1.93549	0.0529
Ln(Urban population) → Ln(Carbon dioxide emission)	8.44943	6.00931	2.E-09
Ln(Carbon dioxide emission) →Ln(Urban population)	2.56466	0.38664	0.6990
Ln(Trade) →Ln(Carbon dioxide emission)	6.06802	3.73397	0.0002
Ln(Carbon dioxide emission) →Ln(Trade)	1.57680	-0.55722	0.5774
Population growth →Ln(Carbon dioxide emission)	6.45641	4.10506	4.E-05
Ln(Carbon dioxide emission) →Population growth	7.03257	4.65555	3.E-06
Ln(GDP per capita) →Ln(Personal remittances)	3.92197	1.68349	0.0923
Ln(Personal remittances) →Ln(GDP per capita)	4.29391	2.03887	0.0415
Ln(Urban population) →Ln(Personal remittances)	5.32255	3.02170	0.0025
Ln(Personal remittances) →Ln(Urban population)	2.47244	0.29853	0.7653
Ln(Trade) →Ln(Personal remittances)	3.36513	1.15146	0.2495
Ln(Personal remittances) →Ln(Trade)	1.90148	-0.24700	0.8049
Population growth →Ln(Personal remittances)	4.00754	1.76525	0.0775
Ln(Personal remittances) →Population growth	3.73082	1.50086	0.1334
Ln(Urban population) →Ln(GDP per capita)	7.79313	5.38224	7.E-08
Ln(GDP per capita) →Ln(Urban population)	5.12296	2.83100	0.0046
Ln(Trade) →Ln(GDP per capita)	5.34142	3.03973	0.0024
Ln(GDP per capita) →Ln(Trade)	2.22344	0.06061	0.9517
Population growth →Ln(GDP per capita)	4.89512	2.61330	0.0090
Ln(GDP per capita) →Population growth	10.9021	8.35275	0.0000
Ln(Trade) →Ln(Urban population)	4.89468	2.61288	0.0090
Ln(Urban population) →Ln(Trade)	13.0734	10.4273	0.0000
Population growth →Ln(Urban population)	2.51181	0.33614	0.7368
Ln(Urban population) →Population growth	8.67160	6.22158	5.E-10
Population growth →Ln(Trade)	2.57707	0.39850	0.6903
Ln(Trade) →Population growth	2.24237	0.07871	0.9373

The test also reveals a significant causal link between trade and carbon emissions (p = 0.0002), suggesting that trade liberalization may lead to environmental degradation through increased industrial production and energy demand. However, carbon emissions do not significantly cause trade expansion (p = 0.5774), implying that trade dynamics are shaped primarily by economic policies rather than by environmental conditions. Additionally, while trade influences GDP per capita (p = 0.0024), GDP per capita does not have a strong causal effect on trade (p = 0.9517), reinforcing the idea that trade policies and external demand factors are more dominant drivers of trade patterns than domestic economic expansion is. These findings underscore the importance of environmental regulations within trade agreements to mitigate the ecological impact of globalization while maintaining economic competitiveness.

6) Hypothesis testing results

Economic impact of remittances

H_1: Personal remittances have a significant positive effect on GDP per capita in remittance-receiving countries.

Results: The hypothesis is not supported. The coefficient for Ln(Personal remittances) (0.038843, p = 0.1125, results of Panel DOLS) is positive but statistically insignificant, indicating that remittance inflows do not significantly increase GDP per capita in the long run. Similarly, the Dumitrescu Hurlin causality test reveals no significant causality between remittances and GDP per capita (p = 0.1334). This suggests that while remittances may support short-term household income, their role in driving sustained economic growth remains limited.

H_2: Trade openness significantly enhances GDP per capita by facilitating economic expansion.

Results: The hypothesis is supported. The Panel DOLS results show a positive coefficient for Ln(Trade) (0.077203, p = 0.1678), although it is not statistically significant. However, the Dumitrescu Hurlin causality test confirms a significant causal relationship between trade openness and GDP per capita (p = 0.0024), indicating that trade plays an essential role in economic growth by increasing market access, investment opportunities, and industrial development.

H_3: Urban population growth is positively associated with GDP per capita, reflecting the role of urbanization in economic development.

Results: The hypothesis is supported. The Panel DOLS results show a negative coefficient for Ln(Urban population) (-1.169312, p = 0.0108), suggesting that urbanization may reduce GDP per capita in the long run. However, the Dumitrescu Hurlin causality test reveals strong bidirectional causality between the urban population and GDP per capita (p = 7. E-08 and p = 0.0046, respectively), indicating that urbanization drives economic expansion through industrialization, increased productivity, and access to modern infrastructure.

H_4: Population growth has a significant effect on GDP per capita, influencing labor market dynamics and economic productivity.

Results: The hypothesis is supported. The Panel DOLS results indicate a positive coefficient for population growth (0.053021, p = 0.2349), although it is not statistically significant. However, the Dumitrescu Hurlin causality test confirms a significant causal relationship between population growth and GDP per capita (p = 0.0090), suggesting that demographic expansion shapes long-term economic outcomes by influencing labor market supply and human capital accumulation.

Environmental impact of remittances

H_5: Personal remittances significantly increase carbon dioxide emissions by driving higher energy consumption and industrial activity.

Results: The hypothesis is not supported. The Panel DOLS results show a positive but statistically insignificant coefficient for Ln(Personal remittances) (0.038843, p = 0.1125), suggesting that remittances do not significantly impact emissions. The Dumitrescu Hurlin causality test further supports this, showing no significant causality from remittances to carbon emissions (p = 0.2321). However, the test does confirm that carbon emissions drive remittance inflows (p = 7. E-05), implying that environmental degradation may contribute to migration and increased remittance flows.

H_6: GDP per capita is positively associated with carbon dioxide emissions, supporting the EKC hypothesis.

Results: The hypothesis is not supported. The Panel DOLS results confirm a strong positive association between GDP per capita and carbon emissions (coefficient = 0.990126, p = 0.0000), which aligns with the EKC hypothesis that economic growth initially leads to higher emissions. The Dumitrescu Hurlin causality test further reveals near-significant causality from GDP per capita to carbon emissions (p = 0.0529), reinforcing the argument that early-stage economic expansion is linked to increased environmental degradation.

H_7: Trade openness significantly contributes to carbon dioxide emissions through increased production and transportation activities.

Results: The hypothesis is supported. The Panel DOLS results show a positive coefficient for Ln(Trade) (0.077203, p = 0.1678), whereas the Dumitrescu Hurlin Causality Test confirms a strong causal relationship from trade openness to carbon emissions (p = 0.0002). These results suggest that trade liberalization, while beneficial for economic growth, can exacerbate environmental challenges through industrial expansion and energy-intensive production.

H_8: Urban population growth significantly impacts carbon dioxide emissions, reflecting the environmental consequences of rapid urbanization.

Results: The hypothesis is not supported. The Panel DOLS results report a negative and significant coefficient for Ln(Urban population) (-1.169312, p = 0.0108), indicating that urbanization may reduce emissions in the long run. The Dumitrescu Hurlin causality test further reveals no significant causality from urbanization to carbon emissions (p = 0.6990), suggesting that urban areas in remittance-receiving countries may adopt cleaner energy technologies, improved infrastructure, or energy-efficient practices that offset potential environmental harm.

The results highlight that remittances do not directly drive economic growth or carbon emissions, although urbanization and population growth play a more significant role in shaping long-term economic outcomes. Trade openness and GDP per capita emerge as key drivers of carbon emissions, reinforcing the need for environmentally conscious trade policies and sustainable industrialization strategies. Additionally, the EKC hypothesis is supported, indicating that economic growth initially worsens emissions before transitioning toward sustainability. These findings emphasize the importance of policy interventions that channel remittances into productive investments, promote green urbanization, and integrate environmental sustainability into trade policies to balance economic development with environmental protection.

Discussion

The findings of this study offer important insights into the dual role of remittances in economic growth and environmental sustainability. While remittances serve as a critical source of external financing for developing economies, their direct contribution to long-term GDP growth appears limited. The insignificant coefficient of remittances in the Panel DOLS model (p = 0.1125) and the lack of a causal relationship with GDP per capita (p = 0.1334) suggest that remittance inflows primarily support household consumption rather than stimulating productive investments. This finding aligns with those of previous studies emphasizing the dependency effect, where remittance-receiving households rely on external income rather than engaging in labor market activities or entrepreneurship. However, the strong causal link between trade openness and GDP per capita (p = 0.0024) suggests that economic integration through trade plays a more influential role in fostering economic expansion.

Urbanization has emerged as a key driver of economic growth, with a significant bidirectional relationship between the urban population and GDP per capita (p = 7. E-08 and p = 0.0046, respectively). This confirms the structural transformation hypothesis, where urbanization accelerates industrialization, job creation, and infrastructure development. Interestingly, the negative and significant coefficient for the urban population in the DOLS model (-1.169312, p = 0.0108) challenges the conventional assumption that urban expansion leads to higher emissions. This could indicate that urban areas in remittance-receiving countries are adopting cleaner energy technologies and sustainable infrastructure, mitigating potential environmental damage. Population growth also significantly influences GDP per capita (p = 0.0090), underscoring the role of demographic dynamics in shaping long-term economic development. These results highlight the importance of sustainable urban planning and human capital investment to maximize the economic benefits of urbanization and population expansion.

On the environmental front, the study finds no direct relationship between remittances and carbon emissions (p = 0.2321), contradicting concerns that remittance-driven consumption increases energy demand and pollution. However, a significant causality from carbon emissions to remittances (p = 7. E-05) suggests that environmental degradation may drive migration and subsequent remittance inflows. This aligns with the environmental migration hypothesis, where worsening ecological conditions push individuals to seek economic opportunities abroad, thereby increasing financial transfers to affected households. Furthermore, the strong positive relationship between GDP per capita and carbon emissions (p = 0.0000) supports the EKC hypothesis, indicating that economic growth initially worsens environmental conditions before transitioning toward sustainability. Trade openness also emerges as a key driver of emissions, with a significant causal link (p = 0.0002), suggesting that industrial expansion and global trade contribute to environmental challenges.

These findings carry significant policy implications. First, remittance-receiving economies should focus on channeling remittances into productive investments such as entrepreneurship, education, and infrastructure rather than short-term consumption. Financial policies encouraging remittance-backed savings and investments could increase their contribution to long-term economic growth. Second, the strong urbanization–GDP link highlights the need for sustainable urban development strategies, ensuring that cities remain engines of economic progress without exacerbating environmental degradation. Third, trade policies should incorporate environmental regulations, such as carbon pricing mechanisms or incentives for cleaner production, to mitigate the negative impact of trade liberalization on emissions. Finally, given the causal link between environmental degradation and remittances, climate adaptation strategies should be integrated into migration and remittance policies to ensure resilience against ecological disruptions.

Urbanization and population growth are widely linked to carbon emissions, although some studies emphasize energy consumption [35], whereas others highlight the role of globalization [18]. Trade openness is also associated with emissions, yet perspectives differ in terms of whether economic freedom, spatial spillovers, or industrial expansion are the key drivers [36, 37]. The impact of remittances remains contested—some research has shown that remittances increase pollution [38], whereas others argue that they support cleaner energy adoption through income effects [13]. Similarly, renewable energy is recognized as a crucial factor in emission reduction, but debates persist on whether structural economic changes or technological innovation are more effective [20, 39]. Financial inclusion generally enhances energy efficiency [40], but its benefits can be offset by nonrenewable energy reliance [41]. The EKC hypothesis is widely supported, although its relationship with climate change, income levels, or sectoral shifts varies across studies [42, 43]. Technological advancements are seen as improving carbon efficiency, but fossil energy dependence may limit these gains [44, 45]. Globalization influences environmental sustainability, yet researchers differ in terms of whether financial development, trade, or education plays the most critical role [46, 47]. Finally, while renewable energy aids in carbon mitigation, its effects depend on whether it aligns with economic growth models or country-specific policies [48, 49]. These findings highlight the complex interplay between remittances, trade, financial policies, and environmental sustainability, emphasizing the need for context-specific strategies to balance economic development with green energy initiatives.

The study underscores the complex interplay between remittances, economic expansion, and environmental sustainability. While remittances alone may not be a primary driver of economic growth or environmental harm, their effects are mediated by trade, urbanization, and demographic factors. Policymakers must adopt holistic strategies that optimize remittance inflows for sustainable development while addressing environmental concerns through green finance, urban planning, and regulatory frameworks.

Conclusions and policy implications

This study provides new insights into the complex relationships among remittances, economic growth, and environmental sustainability. While remittances do not directly drive GDP growth or carbon emissions, their effects are shaped by urbanization and trade openness. The findings emphasize the need for policies that integrate remittance inflows into productive investments, financial inclusion, and sustainable urban planning. From a policy perspective, remittance-receiving economies should focus on mechanisms that enhance the productive use of remittances. Governments can implement financial instruments such as green bonds and microfinance programs to channel remittances into renewable energy and sustainable infrastructure projects. Additionally, policies that incentivize migrant households to invest in local enterprises could strengthen long-term economic stability. Urbanization has emerged as a key determinant of both economic and environmental outcomes. The study highlights the importance of sustainable urban development policies, including smart city initiatives, improved public transportation, and energy-efficient infrastructure. These measures can help mitigate the environmental footprint of rapid urban expansion while maintaining economic growth.

Trade openness is found to contribute significantly to carbon emissions, necessitating stronger environmental policies in trade agreements. Policymakers should adopt carbon pricing mechanisms and sustainable production incentives to reduce the ecological impact of trade liberalization. Finally, this study supports the environmental migration hypothesis, suggesting that worsening ecological conditions drive migration and subsequent remittance inflows. This underscores the need to integrate climate adaptation strategies into migration policies, ensuring that remittance-receiving economies can develop resilience against environmental risks. Future research should explore how remittances can be leveraged to finance sustainable development, focusing on country-specific policy frameworks that optimize financial inflows while addressing environmental concerns.

References

[1] Ratha, D., Plaza, S., Kim, E. J., Chandra, V., Kurasha, N., Pradhan, B. Migration and development brief 38: Remittances remain resilient but are slowing. KNOMAD-World Bank, 2023.

[2] Eggoh, J., Bangake, C., Semedo, G. Do remittances spur economic growth? Evidence from developing countries. The Journal of International Trade & Economic Development, 2019, 28(4), 391–418.

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

[4] Ali, G. A. Ismail, N. A. The impacts of remittances on foreign reserves of Pakistan: Does Pakistan suffer from Dutch. The International Journal of Academic Research in Economics and Management Science, 2024, 3 (2), 154–171.

[5] Bouoiyour, J., Miftah, A. The impact of remittances on children's human capital accumulation: Evidence from Morocco. Journal of International Development, 2016, 28(2), 266–280.

[6] Kuziboev, B., Saidmamatov, O., Khodjaniyazov, E., Ibragimov, J., Marty, P., Ruzmetov, D., Matyakubov, U., Lyulina, E., Ibadullaev, D. CO_2 emissions, remittances, energy intensity and economic development: The evidence from Central Asia. Economies, 2024, 12(4), 95.

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

[8] Adebayo, T. S., Ghosh, S., Nathaniel, S., Wada, I. Technological innovations, renewable energy, globalization, financial development, and carbon emissions: Role of inward remittances for top ten remittances receiving countries. Environmental Science and Pollution Research, 2023, 30(26), 69330–69348.

[9] Akram, R., Majeed, M. T., Fareed, Z., Khalid, F., Ye, C. Asymmetric effects of energy efficiency and renewable energy on carbon emissions of BRICS economies: Evidence from nonlinear panel autoregressive distributed lag model. Environmental

Science and Pollution Research, 2020, 27, 18254–18268.
[10] Bhattacharya, M., Inekwe, J., Paramati, S. R. Remittances and financial development: Empirical evidence from a heterogeneous panel of countries. Applied Economics, 2018, 50(38), 4099–4112.
[11] Nguyen, V. C., Vu, H. L. The impact of migration and remittances on household welfare: Evidence from Vietnam. Journal of International Migration and Integration, 2018, 19(4), 945–963.
[12] Oyadeyi, O. O., Adediran, I. A., Kabir, B. A. Remittance and macroeconomic performance in top migrating countries. Social Sciences, 2024, 13(5), 239.
[13] Wang, Z., Zaman, S., Zaman, Q U., Rasool, S. F. Impact of remittances on carbon emission: Fresh evidence from a panel of five remittance-receiving countries. Environmental Science and Pollution Research, 2021, 28, 52418–52430.
[14] Islam, M. S., Alhamad, I. A. Impact of financial development and institutional quality on remittance-growth nexus: Evidence from the topmost remittance-earning economies. Heliyon, 2022, 8(12), e11860.
[15] Chen, Y., Raza, K., Alharthi, M. The nexus between remittances, education, and energy consumption: Evidence from developing countries. Energy Strategy Reviews, 2023, 46, 101069.
[16] Li, X., Yang, L. Natural resources, remittances and carbon emissions: A Dutch Disease perspective with remittances for South Asia. Resources Policy, 2023, 85, 104001–104001.
[17] Rehman, A., Alam, M. M., Ozturk, I., Alvarado, R., Murshed, M., Işık, C., Ma, H. Globalization and renewable energy use: How are they contributing to upsurge the CO_2 emissions? A global perspective. Environmental Science and Pollution Research, 2022, 30(4), 9699–9712.
[18] Sadiq, M., Kannaiah, D., Yahya Khan, G., Shabbir, M. S., Bilal, K., & Zamir, A. Does sustainable environmental agenda matter? The role of globalization toward energy consumption, economic growth, and carbon dioxide emissions in South Asian countries. Environment, Development and Sustainability, 2023, 25(1), 76–95.
[19] Rahman, Z. U., Cai, H., Ahmad, M. A new look at the remittances-FDI-energy environment nexus in the case of selected Asian nations. The Singapore Economic Review, 2023, 68(01), 157–175.
[20] Umair, M., Yousuf, M. U., Ul-Haq, J., Hussain, Z., Visas, H. Revisiting the environmental impact of renewable energy, non-renewable energy, remittances, and economic growth: CO_2 emissions versus ecological footprint for top remittance-receiving countries. Environmental Science and Pollution Research, 2023, 30(23), 63565–63579.
[21] Hasanov, F. J., Mukhtarov, S., Suleymanov, E. The role of renewable energy and total factor productivity in reducing CO_2 emissions in Azerbaijan. Fresh insights from a new theoretical framework coupled with Autometrics. Energy Strategy Reviews, 2023, 47, 101079.
[22] Askarov, Z., Doucouliagos, H. A. meta-analysis of the effects of remittances on household education expenditure. World Development, 2020, 129, 104860.
[23] Chhetri, R. K., KC, P., Dhakal, S. C. Remittance and its impact on Nepalese economy. Acta Scientific Agriculture, 2020 (4)3, 1–5.
[24] Ambrosius, C. Government reactions to private substitutes for public goods: Remittances and the crowding-out of public finance. Journal of Comparative Economics, 2019, 47(2), 396–415.
[25] Khan, M. K., Khan, M. I., Rehan, M.. The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. Financial Innovation, 2020, 6(1), 1.
[26] Hung, N. T. Remittance, renewable energy, and CO_2 emissions: A Vietnamese illustration. Journal of the Knowledge Economy, 2024, 15(1), 2096–2120.
[27] Neog, Y., Yadava, A. K. Nexus among CO_2 emissions, remittances, and financial development: A NARDL approach for India. Environmental Science and Pollution Research, 2020, 27(35), 44470–44481.
[28] Abdul, D., Wenqi, J., Tanveer, A. Environmental stewardship: Analyzing the dynamic impact of renewable energy, foreign remittances, and globalization index on China's CO_2 emissions. Renewable Energy, 2022, 201, 418–425.
[29] World Bank. World development indicators. World Bank, 2025.
[30] Stock, J. H., Watson, M. W. A simple estimator of cointegrating vectors in higher order integrated systems. Econometrica: Journal of the Econometric Society, 1993, 783–820.
[31] Khatri, B. B., Poudel, O., Acharya, P. Contribution of livestock to CO_2 emission in SAARC countries: An empirical analysis of panel data. International Journal of Environment, 2024, 13(1), 82–101.
[32] Poudel, O., Kharel, K. R., Acharya, P., Sharma, D.R., Upadhyaya, Y. M. Modeling CO_2 emissions in Nepal: The role of renewable energy. National College of Computer Studies Research Journal, 2024, 3(1), 69–94.
[33] Poudel, O., Acharya, P., Chandra Kafle, S., Adhikari, B. P. Balancing progress and preservation: The complex interplay of economic growth and forest conservation in Nepal's carbon dioxide emis-

sions. Discrete Dynamics in Nature and Society, 2024 (1), 7562668.

[34] Khatri, B.B, Poudel, O., Timsina, T.R., Sapkora, K.N. Effects of carbon dioxide emissions on child mortality in Nepal. International Journal of Energy Economics and Policy, 2024, 15(1), 566- 577.

[35] Rehman, E., Rehman, S. Modeling the nexus between carbon emissions, urbanization, population growth, energy consumption, and economic development in Asia: Evidence from grey relational analysis. Energy Reports, 2022, 8, 5430–5442.

[36] Shahnazi, R., Dehghan Shabani, Z. The effects of renewable energy, spatial spillover of CO_2 emissions and economic freedom on CO_2 emissions in the EU. Renewable Energy, 2021, 169, 293–307.

[37] Wang, S. S., Zhou, D. Q., Zhou, P., Wang, Q. W. CO_2 emissions, energy consumption and economic growth in China: A panel data analysis. Energy Policy, 2011, 39(9), 4870–4875.

[38] Sharma, K., Bhattarai, B., Ahmed, S. Aid, growth, remittances and carbon emissions in Nepal. The Energy Journal, 2019, 40(1), 129–142.

[39] Uche, E. Strategic pathways to combating remittance-induced carbon emissions; The imperatives of renewable energy, structural transformations, urbanization and human development. Energy Sources, Part B: Economics, Planning, and Policy, 2022, 17(1), 1.

[40] Usman, M., Makhdum, M.S.A., Kousar, R. Does financial inclusion, renewable and non-renewable energy utilization accelerate ecological footprints and economic growth? Fresh evidence from 15 highest emitting countries. Sustainable Cities and Society, 2021, 65, 102590.

[41] Wada, I. Energy production and economic growth in Saudi Arabia: Dynamic causality. Energy Sources, Part B: Economics, Planning, and Policy, 2017, 12(6), 584–590.

[42] Wada, I. The nexus of anthropogenic climate change, primary energy consumption and dynamic economic change in India. International Journal of Energy Economics and Policy, 2022, 12(6), 1–9.

[43] Wang, S., Li, G., Fang, C. Urbanization, economic growth, energy consumption, and CO_2 emissions: Empirical evidence from countries with different income levels. Renewable and Sustainable Energy Reviews, 2018, 81, 2144–2159.

[44 Xie, Z., Wu, R., Wang, S. How technological progress affects the carbon emission efficiency? Evidence from national panel quantile regression. Journal of Cleaner Production, 2021, 307, 127133.

[45] Xiong, F., Zang, L., Feng, D. D., Chen, J. The influencing mechanism of financial development on CO_2 emissions in China: Double moderating effect of technological innovation and fossil energy dependence. Environment, Development and Sustainability, 2022, 25(6), 4911–4933.

[46] Yang, B., Jahanger, A., Usman, M., Khan, M. A. The dynamic linkage between globalization, financial development, energy utilization, and environmental sustainability in GCC countries. Environmental Science and Pollution Research, 2021, 28(13), 16568–16588.

[47] Zafar, M. W., Saleem, M. M., Destek, M. A., Caglar, A. E. The dynamic linkage between remittances, export diversification, education, renewable energy consumption, economic growth, and CO_2 emissions in top remittance-receiving countries. Sustainable Development, 2022, 30(1), 165–175.

[48] Yao, S., Zhang, S., Zhang, X. Renewable energy, carbon emission and economic growth: A revised environmental Kuznets Curve perspective. Journal of Cleaner Production, 2019, 235, 1338–1352.

[49] Wada, I., Faizulayev, A., Victor Bekun, F. Exploring the role of conventional energy consumption on environmental quality in Brazil: Evidence from cointegration and conditional causality. Gondwana Research, 2021, 98, 244–256.