“Relationship between remittances and carbon emissions: An evidence of top five remittance-receiving countries”

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RELATIONSHIP BETWEEN REMITTANCES AND CARBON EMISSIONS: AN EVIDENCE OF TOP FIVE REMITTANCE-RECEIVING COUNTRIES

Abstract

This study examines the environmental effects of remittances in the five largest remittance-receiving countries (India, Mexico, China, the Philippines, and Pakistan) using panel data from 1990 to 2022 sourced from the World Development Indicators. The study employed a quantitative and analytical research design. Remittances are a critical component of economic stability in these countries, yet their impact on carbon emissions and environmental sustainability remains underexplored. The study utilized a dynamic ordinary least squares (DOLS) method to analyze study variables. Unit root and cointegration tests were performed to assess long-run relationships. A dynamic ordinary least squares (DOLS) (pooled estimation) results revealed that GDP per capita and trade openness have significant positive influences on CO_2 emissions. On the contrary, urban population has significant negative influences on CO_2 emissions. In contrast, remittances show no notable effect on CO_2 emissions. Furthermore, the results show significant long-run cointegration among the variables, with GDP per capita, trade openness, and urban population identified as major drivers of CO_2 emissions. These findings indicate that economic growth, trade liberalization, and demographic expansion are key drivers of environmental degradation, while the direct environmental impact of remittances appears minimal. The study recommends policymakers prioritize environmentally sustainable investments to align remittance-driven economic growth with global climate goals.

Keywords remittances, carbon emissions, economic growth, population growth, sustainability, dynamic ordinary least square

JEL Classification Q54, F24, O13, C23

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INTRODUCTION

The global increase in remittances has become a critical factor in the economies of developing countries, significantly impacting income stability, poverty reduction, and economic growth. While remittances significantly contribute to external income and economic stability in developing countries, their environmental implications, particularly regarding carbon emissions, have been underexplored. As remittances influence household consumption and economic activity, questions arise about their potential environmental impact. The rise in remittances plays a critical role in supporting low- and middle-income countries by enhancing household welfare, reducing poverty levels, and promoting overall macroeconomic stability (Kuziboev et al., 2024). These financial inflows provide essential resources for families, boosting income and enabling increased consumption, which helps to improve living standards. However, while the positive effects of remittances on economic well-being are undeniable, they can also trigger higher energy demands by encouraging economic activities that rely on greater resource consumption. This, in turn, leads to increased CO_2 emissions, sparking important discussions about their potential environmental consequences and the need for sustainable economic practices (Dash et al., 2024).

The environmental impact of remittances is particularly relevant in countries that are both major recipients of remittances and significant contributors to global carbon emissions, such as China, India, and Mexico. In these economies, the rapid pace of urbanization and industrialization, combined with rising remittance flows, presents a dual challenge: maintaining economic growth while managing the environmental consequences. However, the link between remittance-driven economic activities and environmental degradation remains underexplored in empirical research (Ahmad et al., 2019a). Remittance-receiving countries often experience heightened energy demand and consumption due to remittance-funded improvements in housing, transportation, and other areas, potentially resulting in elevated CO_2 emissions (Eggoh et al., 2019). Balancing these economic benefits with sustainable practices remains a challenge, highlighting the need for policies that address both developmental and environmental objectives. Sustainable development offers insights into how financial inflows like remittances might be leveraged to promote green growth, aligning economic progress with environmental stewardship (Saidi & Hammami, 2015; Zafar et al., 2022).

Policymakers must understand the complex relationship between financial inflows, economic growth, and environmental sustainability in remittance-dependent economies in order to balance economic development with environmental conservation. However, with appropriate policy interventions, remittances could be harnessed to support sustainable development, promoting investments in cleaner energy and more efficient technologies. It is crucial to identify the conditions under which remittances can be leveraged to balance economic progress with environmental sustainability.

1. LITERATURE REVIEW AND HYPOTHESES

The relationship between remittances, economic growth, and environmental sustainability is receiving increasing attention, as remittances significantly impact the economic and social conditions of many developing countries (Kuziboev et al., 2024). While the positive economic effects of remittances, such as poverty reduction and enhanced living standards, are well established, their environmental impact, especially concerning carbon emissions, has not been fully explored (Wang et al., 2021; Dash et al., 2024).

In many developing nations, economic growth has historically been linked to rising carbon emissions, driven by industrial growth, urbanization, and greater energy demand (Shahbaz et al., 2011; Farhani & Ozturk, 2015). According to the Environmental Kuznets Curve (EKC) hypothesis, emissions tend to rise in the early stages of economic development but begin to decline once income levels surpass a certain threshold, allowing for investments in cleaner technologies (Grossman & Krueger, 1995; Dogan & Aslan, 2017). Research on emerging economies like China and India has shown that rapid industrialization leads to a significant increase in CO_2 emissions, highlighting the need for policies that promote sustainable development (Khatri et al., 2024a; Rahman et al., 2023; Wang et al., 2011). However, the role of remittances in influencing the relationship between economic growth and environmental degradation remains underexplored. Since remittances often drive economic activity, they may indirectly contribute to carbon emissions by boosting consumption and supporting industrial growth.

Recent studies have begun to explore remittances as potential contributors to environmental degradation. Moreover, remittances are commonly linked with economic benefits like poverty alleviation and increased household spending (Bhattacharya et al., 2018; Ahmad et al., 2019a); however, their environmental impact is less clear. For example, remittances may lead to greater energy consumption if households use additional income to acquire energy-intensive goods or invest in real estate, both of which have high carbon footprints (Akinlo, 2022;

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Ahmad et al., 2019b). Evidence from China indicates that remittances contribute to environmental degradation, especially in areas with intense industrial activity (Ahmad et al., 2019b). Kuziboev et al. (2024) further demonstrate that remittances in Central Asia drive economic activities that increase energy use, thereby contributing to environmental stress. These findings align with the broader literature linking economic growth to carbon emissions, as proposed by the EKC hypothesis (Dogan & Aslan, 2017).

Conversely, remittances may mitigate environmental degradation by financing investments in cleaner energy technologies or sustainable infrastructure, which could reduce CO_2 emissions (Attiaoui et al., 2017). For instance, in Africa, remittances can potentially reduce environmental degradation by enabling investments in cleaner technologies and efficient energy sources (Farhani & Ozturk, 2015). In African economies, remittances have even been shown to fund renewable energy technologies, decreasing the environmental footprint of energy consumption (Saidi & Hammami, 2015; Zafar et al., 2022). Remittances can also promote sustainable agricultural practices, reduce deforestation, and improve water resource management (Azizi, 2020). Thus, while remittances may initially increase carbon emissions, they hold the potential to contribute to long-term environmental sustainability through targeted investments. This complex relationship between remittances and carbon emissions may depend on the specific ways remitted funds are utilized within recipient economies.

Factors like GDP per capita, population growth, trade openness, and urbanization make the link between remittances and carbon emissions more complex. Studies show that as the economy grows, energy use and environmental damage often increase (Ehigiamusoe & Dogan, 2022; Wang et al., 2018). The dynamics of remittances are further affected by population growth and urbanization, both of which are significant drivers of carbon emissions, particularly in countries experiencing rapid demographic shifts (Farhani & Ozturk, 2015; Hashmi et al., 2021). For example, countries like Mexico and India, which have high urbanization rates, also face increased energy demand and environmental degradation (Ehigiamusoe & Dogan, 2022; Wang et al., 2018). Similarly, large remittance-receiving countries such as China, India, and Mexico have experienced environmental challenges due to rapid economic growth and urbanization (Ahmad et al., 2019b; Munir et al., 2020).

Trade openness also influences CO_2 emissions, as increased industrial output resulting from trade can raise emissions levels (Shaheen et al., 2020). However, trade may also facilitate the import of cleaner technologies, potentially offsetting some of the environmental impacts of economic growth. The combined impact of remittances, urbanization, and trade openness on carbon emissions underscores the importance of further research, particularly in developing economies.

While economic growth and remittances may lead to increased emissions, renewable energy presents a viable solution to reduce these effects. Studies emphasize the importance of renewable energy in cutting carbon emissions, especially in developing economies like the BRICS countries (Akram et al., 2020). Integrating renewable energy and improving energy efficiency can lower the carbon intensity of economic activities, suggesting that remittance-receiving countries might leverage these financial flows to support green growth (Khan et al., 2020). As countries expand renewable energy portfolios, the environmental impact of remittances may shift, with remittance-receiving households potentially investing in sustainable energy solutions, thereby reducing fossil fuel dependence and supporting sustainable development goals.

Remittances play a crucial role as an external income source in many developing countries, driving economic growth and poverty reduction. Research has consistently highlighted the positive effects of remittances on household welfare, consumption, and investments in education and healthcare (Ahmad et al., 2019a; Askarov & Doucouliagos, 2020). For example, Ahmad et al. (2019a) found that remittances help alleviate poverty in ASEAN and SAARC countries by improving income stability and reducing economic vulnerability. Similarly, Imran et al. (2021) emphasize how remittances contribute to economic growth in South Asia, while Bhattacharya et al. (2018) argue that such financial inflows promote financial development across different nations. However, these studies mostly focus on the economic benefits of remittances, leaving their environmental impact largely unexplored.

The complex interplay between remittances, economic growth, and environmental sustainability underscores the need for nuanced understanding. While remittances are crucial for poverty alleviation and economic development, they may also impact environmental quality if not properly managed. For instance, trade openness and economic liberalization accompanying remittance inflows can drive industrial growth and emissions (Shaheen et al., 2020). Conversely, remittances could be channeled toward sustainable initiatives like renewable energy projects, aligning economic growth with environmental goals (Khan et al., 2020).

The existing literature presents a complex relationship between remittances and carbon emissions. While remittances contribute to economic growth and poverty reduction, they may also lead to environmental harm, particularly in economies undergoing rapid industrialization. For countries receiving remittances, it is crucial to develop policies that promote both economic and environmental sustainability. Encouraging the use of remittances for investments in renewable energy and energy-efficient technologies could help reduce the environmental impact of economic growth (Alshubiri & Elheddad, 2020).

To sum up, remittances play a crucial role in fostering economic growth; nevertheless, their effects on the environment differ depending on various socio-economic characteristics. Research should focus on strategies that allow recipient countries to align remittances with sustainability objectives, fostering sustainable and environmentally conscious growth. In countries that rely heavily on remittances, this approach could achieve a harmonious equilibrium between environmental protection and economic development, allowing for sustainable development.

This study seeks to explore the connection between remittances and carbon emissions in the five largest remittance-receiving countries. Furthermore, the study addresses the significant role of remittances in stimulating economic activities that may impact carbon emissions and emphasizes the importance of policy measures that align remittance utilization with environmental sustainability. For this purpose, this study formulates and analyzes the following hypotheses:

H1: *Remittances have a significant positive impact on carbon emissions.*

H2: *GDP per capita is positively associated with carbon emissions.*

H3: *Trade openness significantly contributes to carbon emissions.*

H4: *Population growth positively affects carbon emissions in remittance-receiving countries.*

H5: *Urban population significantly affects carbon emissions.*

2. METHODS

This study primarily adopts analytical and quantitative research design. It uses the Dynamic Ordinary Least Squares (DOLS) method to examine the impact of remittances on carbon emissions in five major remittance-receiving countries: India, Mexico, China, the Philippines, and Pakistan (World Bank, n.d.). These countries were selected due to their status as some of the largest recipients of remittances globally, and the study aims to assess the economic and environmental effects of remittance flows. Remittances are crucial to the economies of these nations, significantly supporting household income and promoting economic stability (Dash et al., 2024). These countries exhibit diverse economic structures and stages of development, offering a broad comparative framework. For example, China and India are rapidly growing economies with large populations, urbanization, and industrial expansion, all contributing to higher CO_2 emissions (Wang et al., 2011; Ahmad et al., 2019b).

In contrast, Mexico and the Philippines rely heavily on remittances for domestic consumption and poverty alleviation, but their industrial sectors also contribute to environmental degradation (Bhattacharya et al., 2018; Shaheen et al., 2020).

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Table 1. Variables, abbreviations, units, and data

Variable	Symbol	Unit	Source
Carbon dioxide emission	CO_2	Metric tons per capita	World Bank (n.d.)
Personal remittances	REM	% of GDP	World Bank (n.d.)
GDP per capita	GDPPC	constant 2015 USD	World Bank (n.d.)
Urban population	UP	% of the total population	World Bank (n.d.)
Population growth	PG	annual %	World Bank (n.d.)
Trade openness	TO	% of GDP	World Bank (n.d.)

These countries are also chosen due to their varying levels of trade openness, GDP per capita, and population growth, allowing for a comprehensive analysis of how remittances interact with economic growth and environmental sustainability across different contexts (Farhani & Ozturk, 2015; Attiaoui et al., 2017).

The analysis relies on a balanced panel dataset spanning 1990 to 2022 (Appendix A, Table A1). Key variables include CO_2 emissions (metric tons per capita), personal remittances (as a percentage of GDP), GDP per capita (constant 2015 USD), urban population (percentage of the total population), population growth (annual percentage), and trade openness (percentage of GDP) (World Bank, n.d.). These variables were selected based on prior research highlighting the significance of socio-economic and demographic factors in shaping environmental outcomes (Dash et al., 2024). Table 1 provides details on the variables and their respective units.

Annual data for each variable were collected from the World Development Indicators (WDI) database to create a balanced panel dataset, ensuring consistent definitions and measurements across countries.

This study applied the Levin, Lin, and Chu (LLC), Im, Pesaran, and Shin (IPS), and Maddala and Wu–Augmented Dickey-Fuller (MW-ADF) panel unit root tests to examine the stationarity of variables. The LLC test is considered a pooled panel unit root test, the IPS test accounts for heterogeneity, and the MW test adopts a nonparametric approach. These methods are based on the frameworks developed by Maddala and Wu (1999) and Kao and Chiang (2001).

If all variables are integrated at the first level, cointegration tests are conducted to explore their possible long-term relationships. In this study, the Kao and Fisher tests, which are based on the Johansen methodology, were employed. The Kao and Pedroni tests used the residual-based Engle-Granger two-step procedure, while the Fisher test assessed the null hypothesis of no cointegration.

Upon confirming cointegration, the study applies DOLS to estimate long-run coefficients. This method accounts for short-term dynamics and non-stationary panel data and incorporates leads and lags of regressors to handle endogeneity (Kao & Chiang, 2001). The model specification is as follows:

$$CO_{2it} = \beta_0 + \beta_1 REM_{it} + \beta_2 GDPPC_{it} + \beta_3 UP_{it} + \beta_4 PG_{it} + \beta_5 TO_{it} + \varepsilon_{it}. \quad (1)$$

In this model, "i" stands for the country and "t" represents the time period. The study model also takes into account a non-linear relationship between remittance, GDP and carbon emissions in order to reflect the dynamics of the environmental impact of economic expansion (Grossman & Krueger, 1995; Wang et al., 2021). This model is specified as:

$$\ln\left(CO_{2it}\right) = \beta_0 + \beta_1 L\left(CO_{2it}\right) + \beta_2 L\left(REM_{it}\right) + \beta_3\left(LGDPPC_{it}\right) + \beta_4 L\left(UP_{it}\right) + \beta_5 L\left(PG_{it}\right) + \beta_6 L\left(TO_{it}\right) + \varepsilon_{it}, \quad (2)$$

where $\ln(CO_{2it})$ = The logarithm of CO_2 emissions for the i^{th} country at time t. $L(CO_{2it})$ = The lagged value of the i^{th} country's CO_2 emissions at time t. $L(REM_{it})$ = The lagged value of a variable remittance for the i^{th} country at time t. $L(GDPPC_{it})$ = The lagged value of GDP per capita for the i^{th} country at time t. $L(UP_{it})$ = The lagged value of urban population for the i^{th} country at time t. $L(PG_{it})$ = The lagged value of population growth for the i^{th} country at time t. $L(TO_{it})$ = The lagged value of trade openness for the i^{th} country at time t. α_i = ith country's unit-specific fixed effect. ε_{it} = error term; β_i = coefficients.

Due to the accumulation of leads and lags among the explanatory variables, this estimator consequently solves the problems of small sample bias, endogeneity, and autocorrelation (Stock & Watson, 1993).

This study uses the Dumitrescu and Hurlin (DH) causality test to examine causal relationships among panel variables, addressing cross-sectional dependencies effectively. The DH test offers insights into causality by highlighting interconnections between countries and variables.

3. RESULTS

3.1. Descriptive statistics

Table 2 summarizes the descriptive statistics for the main variables examined in this study, which include CO_2 emissions, remittances, GDP per capita, urban population, population growth, and trade openness.

Table 2 provides a statistical overview of key economic and environmental variables, showcasing significant variation across countries. The mean and median values highlight potential skewness, such as CO_2 emissions (mean: 0.5457; median: 0.2624) and remittances (mean: 0.6197; median: 1.0266), indicating uneven distribution. The wide range between maximum and minimum values, such as CO_2 emissions (–0.5873 to 2.1977) and remittances (–3.3983 to 2.5482), reflects disparities in industrialization and economic reliance. Standard deviations reveal notable variability, especially for remittances (1.4415), while skewness and kurtosis values indicate asymmetrical and heavy-tailed distributions for certain variables, like population growth (skewness: –1.3605; kurtosis: 6.3967). With 165 observations for most variables, the dataset captures diverse economic and environmental contexts. These insights emphasize the interplay between economic growth, trade, urbanization, and environmental sustainability, offering valuable inputs for policy design targeting sustainable development and cleaner technologies.

3.2. Covariance analysis

Table 3 displays the covariance analysis of the key variables, highlighting the correlation coefficients between CO_2 emissions, remittances, GDP per capita, urban population, population growth, and trade openness. This analysis helps to understand the strength and direction of the relationships among these variables, with significant correlations indicated by their corresponding probability values (Khatri et al., 2024b).

Table 3 presents the covariance analysis of economic and environmental variables, revealing the strength and direction of relationships between these variables. Positive covariance values indicate that two variables move in the same direction, whereas negative values suggest an inverse relationship. For instance, the covariance between CO_2 emissions and trade is positive, signifying that higher trade volumes are associated with increased emissions. In contrast, the negative covariance between CO_2 emissions and remittances implies that higher remittance inflows may reduce emissions, potentially through improved household energy efficiency or investment in cleaner technologies.

Similarly, urbanization shows a positive covariance with trade and population growth, reflecting the interconnectedness of economic activities in urban centers and demographic dynamics. The analysis underscores the complex interactions be-

Table 2. Descriptive statistics of key economic and environmental variables

Statistics	$LNCO_2$	LNREM	LNGDPPC	LNUP	LNPG	LNTO
Mean	0.5457	0.6197	7.8164	3.7701	0.3443	3.7622
Median	0.2624	1.0266	7.5160	3.7812	0.4215	3.7766
Maximum	2.1977	2.5482	9.3550	4.3981	1.2069	4.4817
Minimum	–0.5873	–3.3983	6.2765	3.2405	–2.4163	2.7412
Std. Dev.	0.8162	1.4415	0.9119	0.3515	0.5447	0.3934
Skewness	0.4571	–0.9267	0.3726	0.4503	–1.3605	–0.1459
Kurtosis	1.7970	2.9493	1.8051	1.9777	6.3967	2.3601
Observations	165	165	165	165	164	165

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Table 3. Covariance analysis of economic and environmental variables

Covariance Analysis: Ordinary						
Correlation						
Probability	**$LNCO_2$**	**LNREM**	**LNGDPPC**	**LNUP**	**LNPG**	**LNTO**
$LNCO_2$	1	–	–	–	–	–
LNREM	−0.6557	1	–	–	–	–
	0	–	–	–	–	–
LNGDPPC	0.8313	−0.2235	1	–	–	–
	0	0.004	–	–	–	–
LNUP	0.6529	−0.0081	0.9509	1	–	–
	0	0.9184	0	–	–	–
LNPG	−0.7856	0.5789	−0.5460	−0.3152	1	–
	0	0	0	0	–	–
LNTO	0.2799	0.2834	0.5267	0.5801	−0.2238	1
	0.0003	0.0002	0	0	0.004	–

tween environmental sustainability and economic growth. For instance, trade and urbanization are linked to higher emissions, highlighting the environmental trade-offs of economic expansion. Conversely, the mitigating role of remittances points to opportunities for integrating financial inflows into green development strategies. This covariance analysis provides critical insights for designing policies that balance economic growth with environmental conservation.

3.3. Trends in economic and environmental variables

Figure 1 illustrates the trends of key economic and environmental variables across multiple countries, providing insights into the dynamics of CO_2 emissions, remittances, GDP per capita, urban population, population growth, and trade openness over time.

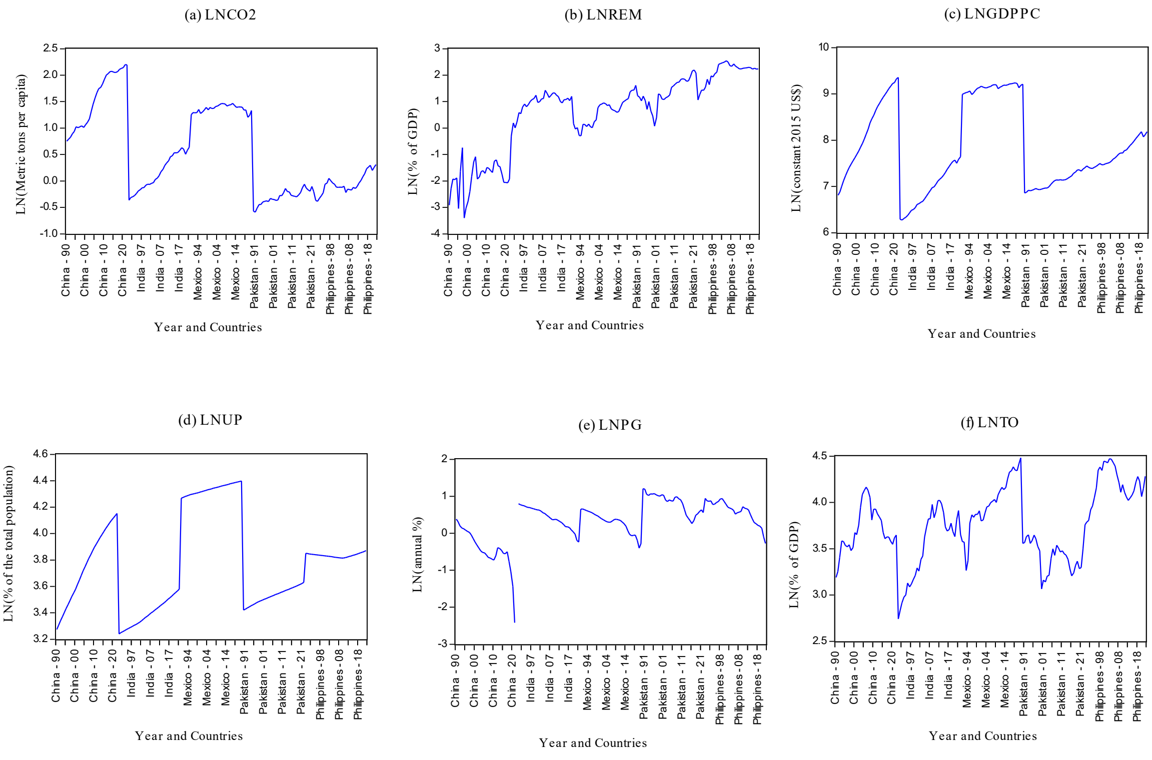

Figure 1. Trends in economic and environmental variables

Figure 1 illustrates the temporal trends in key economic and environmental variables, offering insights into their dynamics over the observed period. The graphical representation highlights the interplay between economic growth, trade, urbanization, and environmental indicators such as CO_2 emissions.

A consistent upward trajectory in CO_2 emissions aligns closely with trends in trade and urbanization, suggesting that economic activities and the expansion of urban areas have significantly contributed to environmental pressures. Trade, represented as a percentage of GDP, exhibits cyclical fluctuations but an overall increasing trend, mirroring global integration and economic liberalization. Urbanization follows a steady rise, reflecting the migration of populations to urban centers, which drives industrialization and infrastructure development.

Interestingly, remittances show a more stable trend compared to other economic indicators, indicating their resilience as a financial inflow source. However, the relationship between remittances and environmental variables appears nuanced, as discussed in covariance analysis. Though declining in rate, population growth remains a consistent contributor to economic demand and environmental impact.

3.4. Unit root tests

This study used the unit root tests on panel data to investigate the stationarity of the series. Table A2 provides the results of panel unit root tests, assessing the stationarity of economic and environmental variables. The tests, including Levin, Lin, and Chu (LLC), Im, Pesaran, and Shin (IPS), Fisher-type ADF and PP tests, Hadri Z-statistics, and Heteroscedastic consistent *Z*-statistics, are critical for determining whether the variables contain unit roots – a necessary step for reliable econometric analysis and policy development.

The results show that $LNCO_2$ (CO_2 emissions) is non-stationary at levels across most tests, as evidenced by *p*-values above 0.05, but achieves stationarity after first differencing ($D(LNCO_2)$). This indicates that CO_2 emissions trend with economic activities but stabilize when considering their changes over time. This has important implications, as it suggests that growth-driven emissions require dynamic policy adjustments focusing on managing emission trends rather than absolute levels.

For LNREM (remittances), some tests, such as the Levin, Lin, and Chu test, demonstrate stationarity at levels under specific conditions (e.g., intercept), implying stability in remittance inflows over time. This is significant for developing economies like Nepal, where remittances play a crucial role in maintaining household incomes and supporting GDP.

LNGDPPC (GDP per capita) is non-stationary at levels, reflecting economic fluctuations influenced by external shocks and growth volatility. However, stationarity is achieved after first differencing, highlighting the importance of analyzing growth rates rather than absolute levels to understand economic stability over time.

Similarly, LNUP (urban population) and LNPG (population growth) are non-stationary at levels, reflecting shifts driven by urbanization, migration, and demographic trends. First differencing these variables resolves non-stationarity, providing a clearer picture of the dynamics driving population changes.

LNTO (trade openness) also exhibits non-stationarity at levels but becomes stationary after differencing. This pattern underscores how trade evolves with policy changes, economic liberalization, and global integration but stabilizes once changes over time are considered.

These findings have critical policy implications. The non-stationarity of CO_2 emissions highlights the need for flexible environmental policies to mitigate emissions associated with economic growth. The stability of remittance inflows suggests they can act as a reliable source of external funding, cushioning households, and supporting investments. The results for GDP per capita and trade openness underline the importance of accounting for structural shifts and economic reforms in assessing long-term growth trajectories. Similarly, population dynamics, as reflected in urbanization and growth trends, emphasize the need for targeted planning to support sustainable development in rapidly urbanizing economies.

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3.5. Cointegration

The second test, which checks if the variables have a long-term relationship, should be conducted after the panel unit root test. Panel cointegration can be tested using methods such as those proposed by Maddala and Wu (1999), Kao (1999), and Pedroni (1999). This study used the Maddala and Wu (1999) and Kao (1999) approaches to test for panel cointegration. As proposed by Maddala and Wu (1999), the Johansen-Fisher panel cointegration test is the preferred method for this analysis. The Johansen-Fisher panel cointegration test, which is based on the individual Johansen cointegration test from 1988, is known for its flexibility and ease of use, offering clear and intuitive results. Hanck (2009) suggests that the Johansen-Fisher test performs better than alternative cointegration tests like those proposed by Kao (1999), Larsson et al. (2001), and Pedroni (1999). This test works by combining the p-values of the individual Johansen maximum eigenvalues and trace statistics, refining the Fisher ADF panel unit root test.

Table 4. Kao residual cointegration test

Kao residual cointegration test	t-statistic	Prob.
ADF	–3.434993	0.0003
Residual variance	0.001434	–
HAC variance	0.001977	–

Table 4 presents the results of the Kao residual cointegration test, confirming a long-term relationship among CO_2 emissions, GDP per capita, trade openness, and remittances. The significant ADF t-statistic (–3.434993, p-value = 0.0003) rejects the null hypothesis of no cointegration, demonstrating that these variables move together over time. This indicates that shifts in remittance inflows, economic growth, and trade dynamics exert persistent influences on environmental outcomes in remittance-dependent economies, underscoring the necessity of harmonized policy measures to balance economic development with environmental sustainability. Given the identified cointegration, the application of dynamic ordinary least squares (DOLS) is required. DOLS addresses potential endogeneity and serial correlation issues inherent in cointegrated relationships by incorporating leads, lags, and contemporaneous differences of independent variables. This ensures unbiased and efficient parameter estimates, making DOLS a robust method for analyzing the strength and direction of these long-term interactions and their implications for policymaking.

Table 5 presents the Johansen-Fisher panel cointegration test results, providing robust evidence of long-term relationships among CO_2 emissions, GDP per capita, remittances, and trade openness. The highly significant Fisher statistics (e.g., None: 146.3, p = 0.0000) reject the null hypothesis of no cointegration, affirming stable interlinkages among these variables across the analyzed countries. Economically, this highlights how remittances and trade openness can simultaneously drive economic growth and environmental pressures, reflecting the dual role of these factors in shaping developmental trajectories. The results underscore the necessity of integrated policy measures that harmonize economic and environmental objectives, ensuring sustainable development. Furthermore, these findings advocate for collaborative global strategies to address cross-border environmental challenges while fostering inclusive growth in remittance-receiving nations.

Table 6 presents the significant results of the panel DOLS estimation, revealing the long-term impacts

Table 5. Johansen-Fisher panel cointegration test

Unrestricted cointegration rank test (Trace and Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	146.3	0.0000	58.83	0.0000
At most 1	97.06	0.0000	36.96	0.0001
At most 2	66.74	0.0000	35.24	0.0001
At most 3	39.16	0.0000	27.74	0.0020
At most 4	20.92	0.0217	15.22	0.1242
At most 5	21.71	0.0167	21.71	0.0167

Note: Fisher Stat.* refers to Fisher Statistics.

Table 6. Panel DOLS (Pooled estimation)

Variable	Coefficient	Std. Error	t-statistic	Prob.
LNREM	–0.020087	0.033024	–0.608251	0.5452
LNGDPPC	0.969231	0.152990	6.335253	0.0000
LNUP	–1.018993	0.405839	–2.510827	0.0146
LNPG	0.041607	0.075386	0.551917	0.5829
LNTO	0.199342	0.057749	3.451879	0.0010
R-squared	0.998633	Mean dependent var		0.550792
Adjusted R-squared	0.996839	S.D. dependent var		0.803641
S.E. of regression	0.045182	Sum squared resid		0.130650
Long-run variance	0.001143	–		–

of GDP per capita (LNGDPPC), urban population growth (LNUP), and trade openness (LNTO) on CO_2 emissions. The coefficient for GDP per capita is positive and highly significant (0.969, t = 6.335, p = 0.000), indicating that economic growth is a major driver of emissions. This suggests that higher GDP per capita, likely linked to increased industrial activity and energy consumption, leads to elevated CO_2 emissions. Similarly, trade openness (0.199, t = 3.452, p = 0.001) shows a significant positive effect, reinforcing the notion that expanded trade activities contribute to emissions through production and transportation demands.

Conversely, urban population growth (LNUP) has a significant negative effect on emissions (–1.019, t = –2.511, p = 0.015). This finding implies that urbanization may reduce emissions in the long run, potentially due to more efficient energy use and economies of scale in urban settings. These results highlight the need for sustainable economic growth strategies, regulations to mitigate trade-related emissions, and policies that harness the potential of urbanization to promote energy efficiency and reduce environmental degradation.

3.6. Hypotheses testing results

H1 is not supported. The coefficient for remittances (LNREM) is negative (–0.020087) but statistically insignificant (p = 0.5452). This indicates that remittance inflows do not significantly influence carbon emissions in the studied context, suggesting limited direct environmental implications of remittance-driven activities.

H2 is supported. GDP per capita (LNGDPPC) significantly increases carbon emissions, with a coefficient of 0.969231 (p < 0.0001). This suggests that a 1% increase in GDP per capita corresponds to a nearly 0.97% rise in carbon emissions, aligning with the notion that economic growth intensifies energy consumption and industrial activities, thereby increasing emissions.

H3 is supported. Trade openness (LNTO) has a significant positive coefficient of 0.199342 (p = 0.0010), indicating that a 1% increase in trade openness leads to a 0.2% rise in carbon emissions. This highlights the environmental costs of increased trade, such as higher production and transportation emissions.

H4 is not supported. The coefficient for population growth (LNPG) is positive (0.041607) but statistically insignificant (p = 0.5829). This suggests that while population growth may influence energy demand, its direct impact on carbon emissions is not substantial in the studied sample.

H5 is supported. The coefficient for urban population (LNUP) is negative (–1.018993) and statistically significant (p = 0.0146), indicating a 1% increase in urban population reduces carbon emissions by 1.02%. This counterintuitive result might reflect efficiency gains from urbanization, such as better infrastructure or cleaner technologies in urban settings.

The results underscore the critical role of GDP per capita and trade openness as key drivers of carbon emissions, reflecting the environmental costs of economic growth and global integration. However, remittances and population growth show limited direct impacts on emissions, suggesting that these factors may interact indirectly with other economic and environmental variables. Urban population trends highlight the potential for sustainable urbanization to mitigate emissions. These findings sug-

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gest that targeted policies emphasizing green trade practices, energy-efficient urban planning, and sustainable growth strategies are essential for balancing economic development and environmental sustainability.

3.7. Dumitrescu-Hurlin panel causality test

The Dumitrescu-Hurlin panel causality test (Table 7) provides insights into the causal relationships between key economic and environmental variables across remittance-receiving countries. A significant causality is observed from urban population (LNUP) to carbon emissions ($LNCO_2$), suggesting that urbanization drives energy consumption and emissions due to increased industrialization and transportation activities (W-Stat: 7.65339, $p < 0.01$). However, there is no evidence of reverse causality from emissions to urban population. Similarly, bidirectional causality exists between population growth (LNPG) and carbon emissions, where population growth significantly contributes to increased emissions through higher resource demand ($p < 0.01$), while emissions also influence population growth dynamics, possibly due to migration patterns linked to industrial activities ($p < 0.001$).

Trade openness (LNTO) shows a significant impact on carbon emissions ($p < 0.01$), emphasizing that globalization and trade liberalization contribute to environmental degradation through production and transportation activities. However, the absence of causality from emissions to trade openness ($p = 0.3968$) indicates that trade policies are not directly influenced by environmental concerns. Additionally, a bidirectional relationship is observed between GDP per capita (LNGDPPC) and urban population, with urbanization fostering economic growth through resource concentration and increased activities ($p < 0.01$) and economic growth driving urban migration and infrastructure development ($p < 0.01$). Moreover, trade openness and urban population exhibit mutual causality, suggesting that urban centers support

Table 7. Pairwise Dumitrescu Hurlin panel causality tests

Null Hypothesis	W-Stat.	Zbar-Stat.	Prob.
LNREM does not consistently cause $LNCO_2$	2.89485	0.69129	0.4894
$LNCO_2$ does not consistently cause LNREM	3.62157	1.38118	0.1672
LNGDPPC does not consistently cause $LNCO_2$	2.82604	0.62596	0.5313
$LNCO_2$ does not consistently cause LNGDPPC	3.67493	1.43184	0.1522
LNUP does not consistently cause $LNCO_2$	7.65339	5.20871	2.E-07
$LNCO_2$ does not consistently cause LNUP	2.48784	0.30490	0.7604
LNPG does not consistently cause $LNCO_2$	7.14085	4.71414	2.E-06
$LNCO_2$ does not consistently cause LNPG	6.29892	3.91599	9.E-05
LNTO does not consistently cause $LNCO_2$	5.88245	3.52751	0.0004
$LNCO_2$ does not consistently cause LNTO	1.27417	–0.84728	0.3968
LNGDPPC does not consistently cause LNREM	4.22895	1.95779	0.0503
LNREM does not consistently cause LNGDPPC	2.79002	0.59176	0.5540
LNUP does not consistently cause LNREM	4.28878	2.01458	0.0439
LNREM does not consistently cause LNUP	4.01313	1.75291	0.0796
LNPG does not consistently cause LNREM	4.54885	2.25693	0.0240
LNREM does not consistently cause LNPG	1.10551	–1.00734	0.3138
LNTO does not consistently cause LNREM	4.11689	1.85141	0.0641
LNREM does not consistently cause LNTO	1.33790	–0.78678	0.4314
LNUP does not consistently cause LNGDPPC	7.50965	5.07226	4.E-07
LNGDPPC does not consistently cause LNUP	4.99479	2.68483	0.0073
LNPG does not consistently cause LNGDPPC	3.87923	1.62213	0.1048
LNGDPPC does not consistently cause LNPG	9.54439	6.99269	3.E-12
LNTO does not consistently cause LNGDPPC	4.75470	2.45690	0.0140
LNGDPPC does not consistently cause LNTO	1.81018	–0.33842	0.7350
LNPG does not consistently cause LNUP	2.70095	0.50513	0.6135
LNUP does not consistently cause LNPG	4.48258	2.19410	0.0282
LNTO does not consistently cause LNUP	4.72142	2.42531	0.0153
LNUP does not consistently cause LNTO	14.1441	11.3706	0.0000

trade activities while trade policies drive urbanization through enhanced market access.

Population growth also significantly influences remittance flows ($p = 0.0240$), reflecting that families in growing populations rely on external financial support. However, remittances do not significantly impact population growth ($p = 0.3138$). These findings underscore the interconnected nature of economic and environmental variables, highlighting the need for coordinated policies. Urban planning and clean energy adoption are critical to managing emissions from urban populations, while sustainable trade policies are necessary to mitigate the environmental costs of globalization. Addressing the feedback loop between population growth and emissions is essential to achieving long-term environmental sustainability.

4. DISCUSSION

This study provides valuable insights into the intricate relationships between remittances, GDP per capita, trade openness, urbanization, and carbon emissions in remittance-receiving economies. The findings reveal that GDP per capita and trade openness significantly drive carbon emissions. The strong positive correlation between GDP per capita and CO_2 emissions supports this theory, as higher industrialization and energy use in developing countries contribute to rising emissions (Hongxing et al., 2021; Dash et al., 2024). The remittances do not exhibit a direct environmental impact, contrasting with existing literature such as Kuziboev et al. (2024), who highlighted indirect environmental pressures from remittance-induced economic activities in Central Asia. This divergence suggests that the environmental implications of remittances are context-specific, depending on their allocation across consumption and investment sectors.

The robust positive relationship between GDP per capita and emissions aligns with Li and Lin (2013), who demonstrated the environmental consequences of income-driven industrialization in developing countries. However, this paper extends the understanding by situating these dynamics within remittance-dependent economies, emphasizing that remittance-induced growth could amplify emissions without parallel investments in cleaner technologies. Moreover, trade openness positively impacts emissions, as increased industrial activity often accompanies trade liberalization, although the potential for adopting cleaner technologies should not be overlooked (Khan et al., 2020; Shaheen et al., 2020). This highlights the need for targeted green trade policies in remittance-receiving countries.

Urbanization's significant negative association with emissions contrasts with Hashmi et al. (2021), who argued for a neutral relationship but supports Ahmad et al. (2019b), who identified urban efficiency as a crucial factor for reducing environmental impacts. The findings imply that urban population growth when aligned with effective urban planning and energy-efficient infrastructure could mitigate emissions despite broader economic expansion (Kuziboev et al., 2024). Furthermore, the insignificant effect of population growth on emissions challenges conclusions, suggesting that the energy demand associated with demographic expansion is mitigated in urbanizing economies (Farhani & Ozturk, 2015).

Interestingly, this study finds partial support for the moderating role of GDP per capita in the relationship between remittances and emissions. While remittances alone do not directly drive emissions, they interact with GDP growth to shape environmental outcomes, corroborating Kao and Chiang's (2001) findings on the Environmental Kuznets Curve (EKC) hypothesis, albeit with nuanced dynamics in remittance-dependent contexts. Moreover, trade openness, as a significant driver of emissions, aligns with Attiaoui et al. (2017), yet the absence of substantial renewable energy adoption in this context emphasizes the need for policy intervention to harness trade as a tool for environmental sustainability.

This study enriches the discourse by integrating macroeconomic and environmental perspectives, shedding light on the multifaceted impacts of economic drivers in remittance-receiving economies. Addressing these complex interdependencies contributes to policy frameworks aimed at harmonizing economic growth with environmental sustainability, underscoring the importance of green financial instruments, urban planning, and trade reforms to achieve long-term resilience.

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CONCLUSION

This study investigates the dynamic interplay between remittances, GDP per capita, trade openness, urbanization, population growth, and carbon emissions in remittance-receiving economies. The findings reveal that GDP per capita and trade openness significantly contribute to carbon emissions, highlighting the environmental trade-offs of economic expansion. In contrast, remittances do not directly impact emissions, challenging assumptions about their environmental repercussions. Urbanization demonstrates a mitigating effect on emissions, suggesting that well-planned urban growth can offset environmental pressures. Overall, this study underscores the critical role of economic policies in balancing growth with sustainability. The findings offer several policy implications. First, policymakers should prioritize green growth strategies, ensuring that economic activities driven by GDP growth and trade openness align with environmental sustainability goals. Investments in renewable energy and low-carbon technologies are essential to mitigate emissions. Second, urbanization's role in reducing emissions emphasizes the importance of sustainable urban planning, including energy-efficient infrastructure and green housing initiatives. Third, the limited environmental impact of remittances suggests that directing these funds toward sustainable projects, such as renewable energy or climate-resilient infrastructure, can amplify their positive effects. Lastly, trade policies should integrate environmental considerations, leveraging global trade to facilitate the adoption of clean technologies.

This study makes a significant contribution by examining the environmental implications of economic drivers in the context of remittance-receiving economies, an area that has received limited attention in the literature. Unlike prior research, which often focuses on GDP or trade as isolated factors, this study incorporates a holistic approach, exploring their combined impact alongside remittances and urbanization. The findings on urbanization's mitigating effects and the negligible direct impact of remittances on emissions challenge existing paradigms, offering new insights into the nuanced dynamics of economic and environmental interactions. While this study identifies the limited direct environmental impact of remittances, further investigation can focus on how remittance flows can be leveraged for green investments.

AUTHOR CONTRIBUTIONS

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APPENDIX A

Table A1. CO_2, remittances, GDP, population growth and trade of top five remittance receiving countries

Source: World Bank (n.d.).

Country	Year	CO_2 emissions (metric tons per capita)	Personal remittances, received (% of GDP)	GDP per capita (constant 2015 USD)	Urban population (% of total population)	Population growth (annual %)	Trade (% of GDP)
China	1990	2.12	0.05	905.03	26.44	1.47	24.27
China	1991	2.21	0.10	975.46	27.31	1.36	25.95
China	1992	2.28	0.15	1,100.65	28.20	1.23	30.15
China	1993	2.45	0.14	1,239.13	29.10	1.15	36.06
China	1994	2.55	0.15	1,384.93	30.02	1.13	35.77
China	1995	2.79	0.05	1,520.03	30.96	1.09	34.28
China	1996	2.74	0.19	1,653.43	31.92	1.05	33.81
China	1997	2.79	0.48	1,787.77	32.88	1.02	34.53
China	1998	2.83	0.03	1,909.62	33.87	0.96	32.42
China	1999	2.75	0.05	2,038.21	34.87	0.87	33.52
China	2000	2.90	0.06	2,193.90	35.88	0.79	39.41
China	2001	3.02	0.09	2,359.57	37.09	0.73	38.53
China	2002	3.24	0.16	2,557.89	38.43	0.67	42.75
China	2003	3.71	0.28	2,797.18	39.78	0.62	51.80
China	2004	4.26	0.34	3,061.83	41.14	0.59	59.51
China	2005	4.80	0.15	3,390.72	42.52	0.59	62.21
China	2006	5.30	0.16	3,800.77	43.87	0.56	64.48
China	2007	5.73	0.19	4,319.03	45.20	0.52	62.19
China	2008	5.87	0.20	4,711.64	46.54	0.51	57.61
China	2009	6.26	0.18	5,128.90	47.88	0.50	45.18
China	2010	6.82	0.22	5,647.07	49.23	0.48	50.72
China	2011	7.42	0.22	6,152.70	50.51	0.55	50.74
China	2012	7.60	0.20	6,591.66	51.77	0.68	48.27
China	2013	7.91	0.19	7,056.42	53.01	0.67	46.74
China	2014	7.95	0.29	7,532.79	54.26	0.63	44.91
China	2015	7.80	0.30	8,016.45	55.50	0.58	39.46
China	2016	7.77	0.24	8,516.53	56.74	0.57	36.89
China	2017	7.90	0.23	9,053.23	57.96	0.61	37.63
China	2018	8.24	0.17	9,619.21	59.15	0.47	37.57
China	2019	8.40	0.13	10,155.51	60.31	0.35	35.89
China	2020	8.53	0.13	10,358.17	61.43	0.24	34.75
China	2021	9.00	0.13	11,223.26	62.51	0.09	37.30
China	2022	8.97	0.15	11,555.93	63.56	-0.01	38.35
India	1990	0.69	0.74	537.87	25.55	2.21	15.51
India	1991	0.73	1.22	531.90	25.78	2.17	16.99
India	1992	0.74	1.01	549.24	25.98	2.13	18.43
India	1993	0.76	1.26	563.37	26.19	2.10	19.65
India	1994	0.79	1.79	588.73	26.40	2.04	20.08
India	1995	0.83	1.73	620.70	26.61	2.01	22.87
India	1996	0.85	2.23	654.36	26.82	2.00	21.93
India	1997	0.88	2.48	667.60	27.03	1.97	22.62
India	1998	0.88	2.25	695.29	27.24	1.94	23.70
India	1999	0.93	2.42	742.54	27.45	1.90	24.82
India	2000	0.94	2.75	756.70	27.67	1.88	26.90
India	2001	0.94	2.94	778.51	27.92	1.87	25.99
India	2002	0.96	3.06	793.62	28.24	1.81	29.51
India	2003	0.97	3.46	841.28	28.57	1.73	30.59
India	2004	1.03	2.64	892.60	28.90	1.70	37.50
India	2005	1.05	2.70	947.73	29.24	1.63	42.00

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Table A1 (cont.). CO_2, remittances, GDP, population growth and trade of top five remittance receiving countries

Country	Year	CO_2 emissions (metric tons per capita)	Personal remittances, received (% of GDP)	GDP per capita (constant 2015 USD)	Urban population (% of total population)	Population growth (annual %)	Trade (% of GDP)
India	2006	1.11	3.01	1,008.23	29.57	1.56	45.72
India	2007	1.19	3.06	1,069.25	29.91	1.51	45.69
India	2008	1.24	4.17	1,086.51	30.25	1.44	53.37
India	2009	1.34	3.67	1,155.10	30.59	1.45	46.27
India	2010	1.40	3.19	1,235.16	30.93	1.45	49.26
India	2011	1.47	3.43	1,281.61	31.28	1.42	55.62
India	2012	1.58	3.77	1,333.10	31.63	1.37	55.79
India	2013	1.61	3.77	1,399.45	32.00	1.33	53.84
India	2014	1.71	3.45	1,484.32	32.38	1.26	48.92
India	2015	1.70	3.28	1,584.00	32.78	1.19	41.92
India	2016	1.71	2.73	1,694.47	33.18	1.19	40.08
India	2017	1.79	2.60	1,788.70	33.60	1.16	40.74
India	2018	1.87	2.91	1,883.36	34.03	1.10	43.62
India	2019	1.83	2.94	1,936.03	34.47	1.04	39.91
India	2020	1.65	3.11	1,806.50	34.93	0.97	37.76
India	2021	1.79	2.82	1,965.31	35.39	0.82	45.42
India	2022	1.89	3.32	2,086.08	35.87	0.79	49.97
Mexico	1990	3.50	1.19	8,036.86	71.42	1.92	38.52
Mexico	1991	3.65	0.97	8,197.01	71.82	1.93	35.79
Mexico	1992	3.62	1.02	8,330.26	72.21	1.89	35.55
Mexico	1993	3.65	0.75	8,411.80	72.60	1.85	26.16
Mexico	1994	3.87	0.74	8,623.48	72.99	1.81	29.16
Mexico	1995	3.58	1.15	7,970.64	73.37	1.78	43.67
Mexico	1996	3.69	1.15	8,320.65	73.67	1.74	47.77
Mexico	1997	3.84	1.06	8,770.84	73.93	1.68	46.49
Mexico	1998	4.01	1.17	9,161.90	74.19	1.64	48.03
Mexico	1999	3.83	1.05	9,264.98	74.44	1.60	48.01
Mexico	2000	4.02	1.01	9,581.97	74.72	1.54	49.91
Mexico	2001	3.94	1.27	9,398.35	75.05	1.48	44.74
Mexico	2002	3.94	1.36	9,242.28	75.37	1.44	45.21
Mexico	2003	4.08	2.18	9,222.00	75.68	1.40	48.70
Mexico	2004	4.12	2.42	9,421.29	76.00	1.37	52.04
Mexico	2005	4.22	2.48	9,491.52	76.31	1.35	52.56
Mexico	2006	4.32	2.60	9,813.83	76.62	1.35	54.48
Mexico	2007	4.32	2.50	9,877.70	76.92	1.41	55.26
Mexico	2008	4.27	2.33	9,826.34	77.22	1.46	56.37
Mexico	2009	4.12	2.43	9,074.12	77.52	1.46	54.59
Mexico	2010	4.19	2.06	9,389.07	77.82	1.44	59.27
Mexico	2011	4.22	1.97	9,575.93	78.11	1.42	62.16
Mexico	2012	4.33	1.92	9,782.52	78.41	1.36	64.26
Mexico	2013	4.17	1.81	9,738.71	78.70	1.30	62.69
Mexico	2014	4.01	1.87	9,862.48	78.99	1.21	64.10
Mexico	2015	4.05	2.21	10,021.24	79.29	1.07	70.41
Mexico	2016	4.06	2.64	10,100.50	79.58	0.97	75.69
Mexico	2017	4.04	2.76	10,193.77	79.87	0.94	76.95
Mexico	2018	3.81	2.91	10,296.87	80.16	0.95	80.21
Mexico	2019	3.84	3.05	10,159.44	80.44	0.95	77.46
Mexico	2020	3.33	3.92	9,234.64	80.73	0.82	76.85
Mexico	2021	3.46	4.18	9,728.06	81.02	0.67	83.07
Mexico	2022	3.79	4.20	10,011.25	81.30	0.75	88.39
Pakistan	1990	0.56	5.01	950.88	30.58	3.34	35.03

Table A1 (cont.). CO_2, remittances, GDP, population growth and trade of top five remittance receiving countries

Country	Year	CO_2 emissions (metric tons per capita)	Personal remittances, received (% of GDP)	GDP per capita (constant 2015 USD)	Urban population (% of total population)	Population growth (annual %)	Trade (% of GDP)
Pakistan	1991	0.56	3.39	966.52	30.83	3.31	35.42
Pakistan	1992	0.60	3.22	1,011.63	31.08	2.86	37.69
Pakistan	1993	0.64	2.79	1,001.26	31.33	2.77	38.50
Pakistan	1994	0.64	3.35	1,009.06	31.58	2.89	35.06
Pakistan	1995	0.67	2.82	1,028.97	31.84	2.89	36.13
Pakistan	1996	0.68	2.03	1,047.89	32.09	2.91	38.33
Pakistan	1997	0.69	2.73	1,029.00	32.35	2.83	36.85
Pakistan	1998	0.68	1.88	1,026.50	32.59	2.76	34.01
Pakistan	1999	0.72	1.58	1,035.50	32.78	2.72	32.32
Pakistan	2000	0.71	1.08	1,049.54	32.98	2.82	21.46
Pakistan	2001	0.71	1.50	1,057.87	33.18	2.80	23.58
Pakistan	2002	0.69	3.63	1,059.04	33.38	2.45	23.13
Pakistan	2003	0.70	3.53	1,090.28	33.58	2.35	24.65
Pakistan	2004	0.76	2.98	1,147.00	33.78	2.47	24.81
Pakistan	2005	0.76	2.95	1,201.23	33.98	2.40	29.88
Pakistan	2006	0.80	3.16	1,243.94	34.18	2.38	33.05
Pakistan	2007	0.87	3.26	1,265.36	34.39	2.64	30.79
Pakistan	2008	0.82	3.48	1,258.05	34.59	2.68	34.35
Pakistan	2009	0.81	4.65	1,269.07	34.79	2.54	33.33
Pakistan	2010	0.76	4.93	1,256.69	35.00	2.47	31.99
Pakistan	2011	0.75	5.32	1,261.83	35.20	2.24	32.36
Pakistan	2012	0.75	5.60	1,275.49	35.41	1.91	31.32
Pakistan	2013	0.74	5.66	1,309.70	35.61	1.63	30.89
Pakistan	2014	0.77	6.35	1,343.31	35.82	1.50	29.47
Pakistan	2015	0.80	6.44	1,380.47	36.03	1.40	26.69
Pakistan	2016	0.88	6.32	1,452.19	36.23	1.30	24.70
Pakistan	2017	0.94	5.85	1,495.26	36.44	1.41	25.47
Pakistan	2018	0.87	5.95	1,561.68	36.67	1.62	27.63
Pakistan	2019	0.85	6.93	1,573.83	36.91	1.69	28.91
Pakistan	2020	0.83	8.68	1,526.01	37.17	1.80	26.72
Pakistan	2021	0.90	8.98	1,595.03	37.44	1.89	27.03
Pakistan	2022	0.82	8.05	1,642.28	37.73	1.75	33.03
The Philippines	1990	0.69	2.90	1,704.08	46.99	2.56	42.92
The Philippines	1991	0.68	3.57	1,656.38	46.90	2.40	44.22
The Philippines	1992	0.72	4.20	1,624.35	46.82	2.37	44.99
The Philippines	1993	0.76	4.17	1,620.36	46.73	2.40	50.47
The Philippines	1994	0.80	4.72	1,654.75	46.65	2.18	52.53
The Philippines	1995	0.94	6.33	1,693.81	46.56	2.19	57.33
The Philippines	1996	0.96	5.15	1,752.24	46.48	2.30	63.86
The Philippines	1997	1.05	7.22	1,800.26	46.39	2.35	77.23
The Philippines	1998	1.01	6.89	1,746.53	46.31	2.51	80.08
The Philippines	1999	0.96	7.82	1,759.42	46.22	2.56	77.16
The Philippines	2000	0.94	8.28	1,793.35	46.14	2.38	85.15
The Philippines	2001	0.89	11.10	1,807.71	46.05	2.21	84.90
The Philippines	2002	0.88	11.55	1,837.25	45.97	2.03	83.84
The Philippines	2003	0.89	11.76	1,892.82	45.88	1.98	87.57
The Philippines	2004	0.89	12.07	1,978.34	45.80	1.94	87.13
The Philippines	2005	0.90	12.78	2,037.88	45.71	1.86	83.85
The Philippines	2006	0.80	12.14	2,110.42	45.63	1.68	80.85
The Philippines	2007	0.86	10.54	2,209.35	45.54	1.73	73.64
The Philippines	2008	0.85	10.38	2,264.95	45.46	1.77	67.68

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Table A1 (cont.). CO_2, remittances, GDP, population growth and trade of top five remittance receiving countries

Country	Year	CO_2 emissions (metric tons per capita)	Personal remittances, received (% of GDP)	GDP per capita (constant 2015 USD)	Urban population (% of total population)	Population growth (annual %)	Trade (% of GDP)
The Philippines	2009	0.84	11.34	2,256.73	45.37	1.80	60.89
The Philippines	2010	0.89	10.35	2,373.14	45.33	2.05	66.10
The Philippines	2011	0.87	9.84	2,416.75	45.52	1.96	60.80
The Philippines	2012	0.90	9.40	2,533.74	45.71	1.94	57.84
The Philippines	2013	0.96	9.41	2,654.42	45.90	1.88	55.82
The Philippines	2014	1.01	9.64	2,776.92	46.09	1.64	57.47
The Philippines	2015	1.08	9.72	2,909.86	46.28	1.48	59.14
The Philippines	2016	1.15	9.77	3,076.34	46.48	1.34	61.78
The Philippines	2017	1.26	9.99	3,247.45	46.68	1.29	68.17
The Philippines	2018	1.30	9.75	3,410.94	46.91	1.24	72.16
The Philippines	2019	1.34	9.33	3,575.88	47.15	1.22	68.84
The Philippines	2020	1.22	9.64	3,198.67	47.41	1.15	58.17
The Philippines	2021	1.29	9.31	3,350.98	47.68	0.91	63.48
The Philippines	2022	1.36	9.41	3,577.70	47.98	0.76	72.43

Table A2. Results of panel unit root testing

Null: Unit Root							Null: No Unit Root	
Variable	Deterministic	Levin, Lin and Chu (LLC)	Breitung t-stat	Im, Pesaran And Shin (IPS) W-stat	MW-ADF Fisher Chi-square	MW-PP Fisher Chi-square	Hadri Zstat	Heteroscedastic consistent Zstat
$LNCO_2$	Intercept	–1.0399	–	0.3368	7.6942	7.6027	6.9871***	5.7355***
	Intercept & Trend	0.7968	0.9824	0.9491	5.5524	4.5643	2.8676***	3.1130***
$D(LNCO_2)$	Intercept	–2.0311**	–	–4.1466***	37.1221***	78.4474***	–0.2167	0.0915
	Intercept & Trend	–1.4270*	0.0945	–3.1619***	29.0441***	102.370***	2.0763**	4.1621***
LNREM	Intercept	–2.5367***	–	–2.0661**	24.4604***	36.7902***	5.6852***	5.4173***
	Intercept & Trend	–1.4328*	0.8628	–1.0381	14.2138	22.7737**	4.6241***	4.2128***
D(LNREM)	Intercept	–3.6267***	–	–7.1950***	66.1756***	123.200***	1.6505**	2.6305***
	Intercept & Trend	–2.5735***	–4.8240***	–7.0079***	60.1841***	373.384***	4.1861***	3.7744***
LNGDPPC	Intercept	–2.1801**	–	2.0966	7.4137	7.2839	7.3966***	7.2931***
	Intercept & Trend	0.3393	2.7510	0.3079	9.2288	10.9755	5.0421***	4.6399***
D(LNGDPPC)	Intercept	–3.7183***	–	–4.9618***	46.4091***	84.3952***	2.8407***	2.4646***
	Intercept & Trend	–3.6401***	–1.1525	–4.1399***	36.3468***	243.753***	2.3021**	5.8954***
LNUP	Intercept	1.7702	–	4.1944	3.3573	23.5084***	7.4355***	6.1170***
	Intercept & Trend	–0.9323	–0.7403	1.0650	8.4436	12.3831	6.8197***	6.4239***
D(LNUP)	Intercept	–0.0948	–	0.7210	8.7874	5.4426	6.7337***	5.7277***
	Intercept & Trend	–0.1170	0.3339	0.4084	9.4458	5.3331	5.0563***	3.8218***
LNPG	Intercept	4.9910	–	5.8204	1.4137	1.0367	7.8979***	7.9405***
	Intercept & Trend	4.3975	–1.1784	3.1389	4.5920	1.6558	1.9785**	3.1638***
D(LNPG)	Intercept	1.5002	–	–1.9603**	32.9345***	31.4241***	1.4189*	1.8367**
	Intercept & Trend	2.4328	3.4861	–1.2372	28.0560***	26.6223***	3.9262***	2.1902**
LNTO	Intercept	–1.8135**	–	–0.8563	11.8984	11.3491	4.9302***	3.3467***
	Intercept & Trend	–1.0927	–0.4513	–0.6199	14.6719	7.2484	4.8094***	3.5340***
D(LNTO)	Intercept	–5.7055***	–	–5.0380***	44.6825***	85.3512***	1.1833	1.5523*
	Intercept & Trend	–5.1864***	–1.7416**	–3.7097***	31.6829***	80.2166***	1.7611**	3.9397***

Note: *** Significance at 1%, ** significance at 5%, and * significance at 10%.