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Article

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Remittances and environment quality: Asymmetric evidence from South Asia

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ABSTRACT

Remittances are the largest sources of foreign funds and are critical for economic development in South Asia. However, they have been found to damage the environment by promoting the production and consumption of energy-intensive products and pose challenges for achieving Sustainable Development Goals (SDGs). Against this backdrop, this study examines the role of remittances in environmental degradation using a sample of five South Asian countries from 1990 to 2021. A non-linear multivariate panel ARDL (NARDL) model is applied to investigate the asymmetric long and short-run relationship between the two. Cointegration results suggest that there is a stable long-run relationship among the variables. Empirical findings indicate that positive remittance shocks impact environmental degradation, and adverse shocks have a favourable effect. The causality results show one-way causality from positive and negative shocks to environmental quality, supporting the asymmetric relationship. The control variables, such as trade, financial development, and energy consumption, exacerbate environmental degradation while FDI improves the environmental quality. For robustness, the study uses Ecological Footprints (EPF) as an alternative proxy for environmental quality and confirms the asymmetric long and short-run link between remittances and environmental quality. Based on the results, an integrated approach combining the development and environmental goals is recommended.

1. Introduction

Remittances to developing countries have increased significantly in the last three decades and currently represent the principal source of foreign funds in many developing countries. According to the World Bank (2023), total remittances increased to \$831 billion in 2022 from \$781 billion in 2021, with the bulk of the amount (\$656 billion or more than 79 %) going to developing countries. Remittances are more stable than other capital flows and play a critical role in economic development, particularly in achieving SDGs. Out of 17 SDGs, remittances have links with 15 goals but direct links with goals 13 and 14 related to the environment. If remittances affect the environment adversely, it will have serious implications for SDGs, particularly SDGs such as 2.4 (improving soil quality), 3.9 (substantially reducing the number of deaths from pollution), 7 (clean energy), 11 (clean cities and communities), 12 (responsible consumption and production), 14 and 15 (conservation of water and land).

Previous studies suggest that remittances are critical in ensuring food security, reducing hunger and poverty, and promoting education, health, and financial inclusion for poor households (Ratha, 2013; Chowdhury, 2016; Azizi, 2018; Aregbeshola, 2022; Taghizadeh-Hesary, 2020). In addition, remittances promote financial development, investment, and economic growth by providing capital to small business enterprises (Aggarwal et al., 2011; Ratha, 2013; Kadozi, 2019; Ahmad et al., 2019). They also help to finance the import of critical capital goods and external debt services (Ratha, 2013). Notwithstanding the positive role of remittances in economic development, they are linked with environmental degradation. A large inflow of remittance triggers the consumption and production of traditional energy-intensive goods, leading to environmental degradation by increasing energy consumption. The empirical results are inclusive and vary from sample to sample. For instance, studies (Sharma et al., 2020; Khan et al., 2020; Yang et al., 2021; Rehman et al., 2021; Zafar et al., 2022; Chishti et al., 2023) found a negative effect of remittances on the environment by promoting financial and industrial development, and increasing energy consumption. On the other hand, studies (Usman et al., 2021; Wang et al., 2021; Zafar et al., 2022) found a favourable effect of remittances on the environment by promoting technological innovations and encouraging

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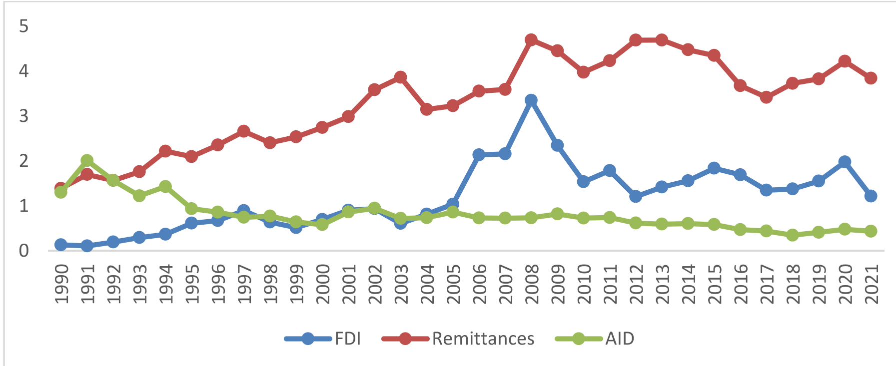

Fig. 1. Relative importance of Remittances vs. FDI and Aid (% of GDP). Source: World Development Indicators, World Bank.

the production and consumption of green goods. Further, Wawizyniak and Doryń (2002) found no link between remittance inflows and the environment, and better institutional quality mitigates the negative environmental impact. Other studies (Rehman et al., 2021; Elbatanony et al., 2021; Islam, 2022) find that the link between remittances and environmental quality is non-linear. Initially, remittances degrade the environment by increasing the consumption and production of traditional goods, but with the rise in income level, remittances promote environmental quality by encouraging green production and consumption. The debate on the link between remittances and the environment is not conclusive and varies from study to study; therefore, there is a need for further research covering different regions, countries, sample periods, and methods. In this context, this study provides additional evidence on this issue by covering five South Asian countries: India, Pakistan, Sri Lanka, Nepal, and Bangladesh. The choice of South Asian countries is due to the following reasons: first, South Asian countries are the major recipients of remittances. According to the World Bank (2022), South Asian countries received about US$176 billion in remittances in 2022, much higher than the combined amount of FDI and Foreign aid (US$ 66 billion). Second, this region is one of the major contributors to environmental pollution, contributing around 9 % of the total CO2 emissions in 2021, and is expected to increase further without intervention (IEA, 2022). Hence, it is important to examine the link between remittances and the environment of this region and devise alternative strategies to promote green growth. Third, studies covering South Asian countries provide contrasting results, and there is a need for further scrutiny. In this context, we pose the following research questions:

(1) Is there any link between remittances and environmental degradation in South Asia?
(2) Does a rise and a fall in remittances have a differential impact on environmental quality?

The novelty of this study is manifold: First, building on the existing literature, this study provides further evidence by examining the long and short-run asymmetric link between the two. For this purpose, this study applies a Panel Non-linear Auto-Regressive Distributed Lag Model (NARDL) that considers the issues of endogeneity, heterogeneity, and cross-section effects. Second, compared to previous studies, this study uses two indicators of environmental quality, CO2 emission and Ecological Footprint (EPF), to confirm the environmental effect of remittances. Third, the study applies a cross-sectionally adjusted panel causality test accounting for the possible asymmetric relationships.

The rest of the study is structured as follows: Section 2 presents the trends and importance of remittances for South Asian countries. Section 3 deals with the literature review. Section 4 presents the data, methodology, and model specification. Section 5 discusses the results. Finally, Section 6 provides the conclusion and policy implications of the study.

2. Trends and importance of remittances for South Asia

Worker remittances to the South increased from $5.6 billion in 1990 to over 82 billion in 2010 and above 176 billion in 2022. South Asia accounts for 21 % of total remittances in 2022, the highest for any other region. In 2022, India ranked first with $111 billion in remittance receipts, and Pakistan, Bangladesh, and Nepal ranked sixth, eighth, and 23rd in the world (World Bank, 2023). For South Asia, remittances are the most important source of external capital flows, much higher than FDI and foreign aid (see Fig. 1). The importance of remittances in gross capital formation, exports, and forex reserves is also very significant.

Fig. 2 presents remittances as a ratio of Gross Capital Formation (GCF) for five South Asian countries. In Nepal, remittances stand at 63 % in 2021, increased from a mere 6 % in 1990. They stayed at 61 %, 17 %, 17 %, and 9 % of GFC for Pakistan, Bangladesh, Sri Lanka, and India in 2021, respectively. Similarly, remittances account for a significant share

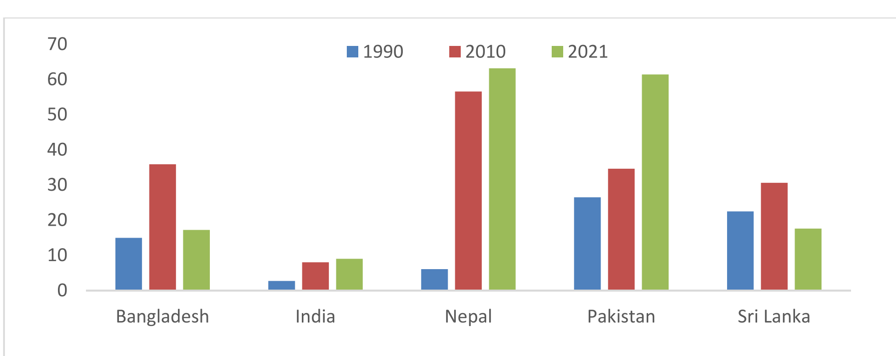

Fig. 2. Remittances as the percentage of Gross Capital Formation. Source: World Development Indicators, World Bank.

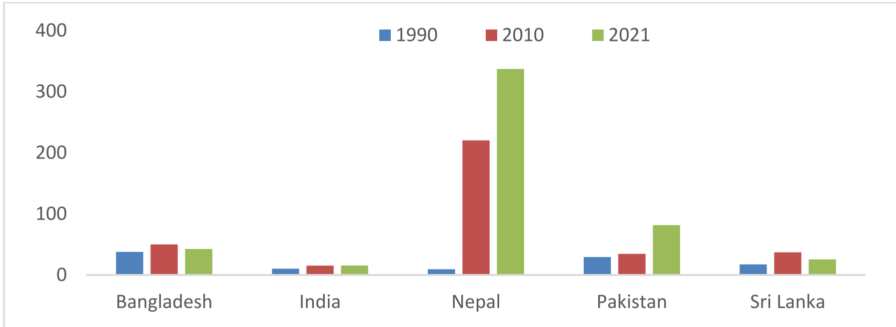

Fig. 3. Remittances as the percentage of Exports. Source: World Development Indicators, World Bank.

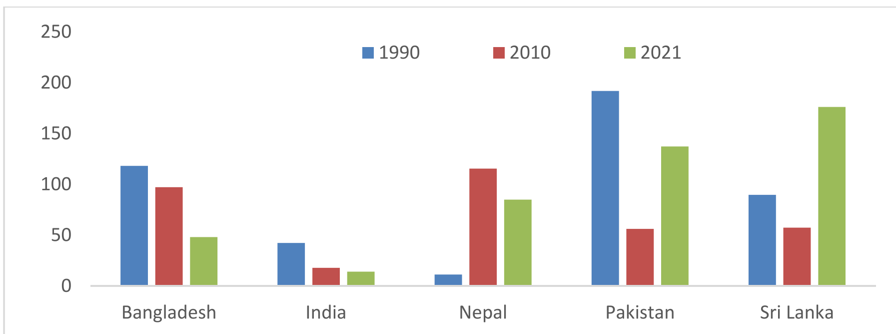

Fig. 4. Remittances as the percentage of Forex Reserves. Source: World Development Indicators, World Bank.

of exports and foreign exchange reserves in five countries (Figs. 3 and 4).

Fig. 3 shows that in Nepal, remittances were 337 % of exports of goods and services, the highest among all countries in 2021. It was high for other South Asia countries except India. For example, it was 81 % for Pakistan, 42 % for Bangladesh, 25 % for Sri Lanka, and 16 % for India in 2021.

The contribution of remittances to the forex reserve is also relatively high in all South Asian countries except India (see Fig. 4). In Sri Lanka, Pakistan, Nepal, and Bangladesh, the remittances stayed at 176 %, 137 %, 85 %, and 48 % of reserves in 2021, respectively. Overall, it is clear that remittances are vital foreign capital for all South Asian countries. For Pakistan, Bangladesh, Sri Lanka, and India in 2021, they remained at 61 %, 17 %, 17 %, and 9 % of GFC, respectively. Similarly, remittances account for a sizeable portion of the five countries' exports and foreign exchange reserves (Figs. 3 and 4).

2.1. Environmental pollution in South Asia

South Asia is one of the most populated regions in the world. It is also the most vulnerable region due to its diversified ecosystem and frequently faces numerous natural disasters like seasonal droughts and floods (WHO, 2015). Most South Asian countries are in the transition phase marked by increasing industrialization, urbanization, and consumption boom following economic liberalization in the early 1990 s. This has resulted in escalating greenhouse emissions and environmental degradation. Higher economic growth through rapid industrialization and surging energy consumption significantly increased greenhouse emissions (Sumaira et al., 2022; Neog and Yadava, 2020). According to Euro Science (2022), of the 50 most polluted cities globally, 44 cities belong to South Asia. Regarding CO2 emission, South Asia ranks fourth after China, Europe, and the USA, contributing 9 % of the total emissions. India and Pakistan are the major contributors to CO2 emissions in South Asia. India is the 4th largest emitter after China, the USA, and the EU. In 2021, India's share of global emissions was 7.5 %, marginally below the EU share (IEA, 2022). Bangladesh also experienced a significant rise in CO2 in recent years. So, there is a possibility of a link between remittances and environmental degradation in South Asia.

3. Literature review

3.1. Nexus between remittances and environment

Theoretically, it is argued that remittances can degrade the environment in various ways (See Appendix Fig. A.1 for more). First, remittances increase household incomes, savings, consumption, and business activities in the recipient country. The increase in business activities would lead to economic growth and environmental degradation, as predicted by the Ecological Kuznet Hypothesis. Additionally, an increase in consumption of both durable and non-durable goods such as steel, automobiles, air conditioners, washing machines, etc., including fossil oil, also leads to environmental degradation through a negative consumption externality (Brown et al., 2020). Indirectly, remittances promote financial development and increase funds for establishing new businesses and expanding existing industries. These increased financial investments in industries convert to more industrial production, leading to more fossil fuel consumption. This produces high CO_2 emissions that harm the environment (Li et al., 2015; Salam and Chishti, 2022). On the other hand, remittance would benefit the environment if the influx of remittances is utilized to finance green investments and environment-friendly technologies (Wang et al., 2021). Further, if households use remittances to consume environmentally preferable goods, then remittances would reduce the environmental problem (Usman et al., 2021). Few others have argued that remittances have a non-linear impact on the environment, implying that a rising (positive shock) impact would differ from declining remittances (negative shock). A positive remittance shock would lead to a negative production externality (Ahmad et al., 2023; Khan et al., 2021). A negative shock would have the exact opposite effect. Others such, as (Ahmad et al., 2023; Elbatanony et al., 2021; Li et al., 2022), argue that initially, remittances may degrade the environment by increasing consumption and production of environmentally polluted goods, but with the rise in income level, remittances may promote environmental quality by encouraging green investment, production, and consumption of environmentally friendly products. So, in the long run, remittances would positively impact the environment (Islam, 2022; Elbatanony et al., 2021). Additionally, studies (Rehman et al., 2021; Khan et al., 2021) argue that remittances may damage the environment by promoting the financial sector and making credit available to firms. In contrast, studies such as (Boufateh and Saadaoui, 2020; Omri et al., 2015; Usman et al., 2021) suggest that financial development may improve environmental quality by encouraging firms to invest more in advanced technology and green products. So, it is unclear whether remittances would degrade or enhance the environment quality, and it depends on whether it propels the consumption and production of dirty or clean goods.

3.2. Previous studies

Recent studies suggest that remittances adversely impact the environment, although results are inconclusive and vary from sample to sample (Qiang and Zhang, 2021; Khan et al., 2020; Wang et al., 2021; Jamil et al., 2022; Ahmad et al., 2023; Zafar et al., 2022). Therefore, the adverse impact of remittances on the environment needs to be controlled or moderated to promote SDGs.

Rehman et al. (2021) examine the nexus between remittances and the environment for six selected Asian countries during 1982–2014. Using the ARDL model, the study finds that in the long run, remittances increase CO2 emissions in Sri Lanka, Pakistan, The Philippines, and Bangladesh. No significant effect is found for China and India. Khan et al. (2020) examine the role of remittances in CO2 emission for BRICS countries from 1986 to 2016 using panel data analysis. The study finds that remittances have a significant degradation effect on the environment. A 10 % rise in remittances causes a 0.17 % reduction in environmental quality in BRICS countries. Zafar et al. (2022) examined the link between remittances, export diversification, and CO2 emissions for 22 developing countries from 1987 to 2017. The findings of this study suggest that remittances reduce environmental pollution, but economic growth increases pollution levels. Usman et al. (2021) investigated the relationship between remittances and environmental quality for a panel of 93 countries from 1990 to 2016. Using panel quantile regression, the study finds that remittances degrade the environment from the 5th to 70th quantiles but have a favourable effect from the 80th to 90th quantiles. In a similar study of 56 developing countries, Elbatanony et al. (2021) find an inverted N-shaped Kuznet curve for remittances in lower-income countries and a U-shaped curve from the 40th to 80th quantiles in upper-middle income countries but a monotonic negative effect from 90th to 95th quantiles. Besides cross-country studies, a few studies also examine the same at the country level, and the results are inconclusive. Ahmad et al. (2023) studied the symmetric and asymmetric relationship between remittances and CO2 in Pakistan using the NARDL model. The findings of this study suggest that remittances increase emissions in Pakistan. A similar conclusion has been reached by Chishti, Dogan, & Zaman, 2023; Chishti & Hameed, 2023; Chishti, 2023 using different methods (wavelet analysis) and data periods (1976Q1 to 2020Q4) for Pakistan. Li et al. (2022) examine the impact of remittances on environmental quality in Ghana. Using three different estimators, FMOLS, DOLS, and Canonical cointegrating regression (CCR), the study finds that remittances deteriorate the ecological quality by increasing CO2 emissions. The studies of Neog and Yadava (2020) for India and Kibria (2022) for Bangladesh further confirm the adverse impact of remittances. Compared to the above studies, few studies have found a positive or favourable effect of remittances on environmental quality (Usman et al., 2021; Wang et al., 2021; Sharma et al., 2020). Kibria et al. (2021) find that energy consumption has an adverse effect on the environment, whereas financial development has a mixed impact in South Asia. Similarly, Kibria (2023) analyzes the nexus between economic complexity and the ecological footprint in Bangladesh. Using the NARDL model, the study finds an asymmetric relationship between economic complexity and EPF. A surge in economic complexity of 1 unit results in an EPF increase of 0.13 units, while a decrease in economic complexity of 1 % reduces EPF by 0.41 %.

Table 1
Data Sources, Definition, and Sample Period.

Variables	Definition	Sample period	Sources
CO2	CO2 emissions (metric tons per capita)	1990–2021	WDI
EPF	Ecological Footprint	1990–2018	Global Footprint Network
PFDI	Per capita FDI	1990–2021	WDI
PENG	Per capita energy consumption (Kg. of oil equivalent)	1990–2021	WDI
MTD	Manufacturing Trade (% of GDP)	1990–2021	WDI
PREM	Per capita Remittances	1990–2021	WDI
FD	Bank credit to the domestic Sector (% of GDP)	1990–2021	WDI

Source: Authors compilation

Recently, a few studies have also examined the strategy for sustainable green development (Chishti et al., 2023; Chishti and Patel, 2023; Jiaduo et al., 2023; Hasan et al., 2023). Chishti et al. (2023) explore the green determinants of sustainable electricity generation to deal with the energy and pollution crisis. The study identifies environmental policy, circular economy approach, energy transition, and geopolitical risk as major determinants of sustainable electricity generation. Similarly, Chishti et al. (2023) emphasize green innovation, particularly green technology to sustain economic growth. Further, Chishti and Patel (2023) emphasize the role of natural resources in mitigating climate mitigation technology required for achieving COP26 targets. Applying the general method of moment quantile-based regression (GMMQR) and panel quantile ARDL techniques, the study finds that natural resources boost climate mitigating technology (CMT) growth by spurring green investment. Hasan et al. (2023) examine the link among economic growth, CO2, education, life expectancy, and technology in Bangladesh. The findings of this study suggest that GDP is the main contributor to CO2 increase. Based on the empirical evidence, the following hypothesis is examined:

Null hypothesis (H_0): Remittances have no influence on the environmental quality in South Asia.

Alternative Hypothesis (H_1): Remittances have a significant impact on the environmental quality in South Asia.

4. Data, methodology, and model specifications

4.1. The data set

This study uses annual data from 1990 to 2021 for five South Asian countries, resulting in 160 observations. The dependent variable is per capita CO2 emission. Alternatively, we also use Ecological Footprint (EPF)[1] for robustness checks. Other than remittances, we include additional explanatory variables such as FDI, energy consumption, and financial development based on previous literature. Table 1 provides detailed information about the data, period of study, and data sources.

[1] In the empirical literature, CO2 is used as the proxy for environmental quality due to its reliability and availability over a long period of time. By definition, CO2 emissions include greenhouse gases and pollution. This, thus, covers the greenhouse gas emissions from consumption and production. Alternatively, some studies use EPF for environmental quality as it represents the capacity to absorb waste, including CO2 emissions. EPF consists of six parameters: forest land, build-up land, grazing land, fishing grounds, carbon, and cropland, and is considered more inclusive proxy for environment quality.

4.2. Econometric approach

The study uses multiple panel econometrics techniques to examine the relationship between environmental quality and remittances. Since we have long panel data covering 1991 to 2021 for five countries, the panel Auto-Regressive Distributed Model (ARDL) is appropriate. The ARDL model provides short and long-run analysis and accounts for potential endogeneity among variables. For this purpose, the study uses Mean Group (MG) estimators and Pool Mean Group (PMG) estimators proposed by Pesaran and Smith (1995) and Pesaran et al. (1999), respectively. The MG estimators assume short- and long-run coefficients to vary across countries, while PMG estimators assume long-run symmetry but allow short-run heterogeneity. The Hausman test is applied by setting the null as long-run symmetric coefficients. To examine the asymmetric relationship between environmental quality and remittances, remittances are decomposed into positive shocks (REM^{+}) and negative shocks (REM^{-}). However, in the presence of the cross-section effect, the MG and PMG estimators are biased and inconsistent (Chudik and Pesaran, 2015). Therefore, to account for the cross-section effect, the study uses Common Correlated Effect pooled mean group (CCEPMG) and Common Correlated Effect mean group (CCEMG) estimators proposed by (Chudik and Pesaran, 2015). Like PMG estimators, the CCEPMG estimators assume long-run slope heterogeneity, and the Hausman test is applied to choose between CCEPMG and CCEMG. In the first step, the study conducts a Unit Root test to examine the non-stationarity of the variables. In addition, the Cross-Sectional Dependence (CD) test is also shown to test the presence of a cross-section effect. In the second step, the study applies a cointegration test to establish a long-run stable relationship among variables. In the third step, the study uses the non-linear ARDL model (MG, PMG, CCEMG, and CCEPMG) to derive long and short-run asymmetric coefficients. In the last step, the study used the Juodis et al. (2021) causality test to infer the direction of causality between environmental quality and remittances.[1]

4.2.1. Panel unit root test allowing for heteroscedasticity and cross-sectional dependence

Given that most of the macro variables are time-varying, the study used heteroscedasticity-robust panel unit tests as suggested by (Herwartz and Siedenburg, 2008; Demetrescu and Hanck, 2012; Herwartz et al., 2017), which are ignored in the previous literature. The study applies Herwartz and Sidenburg (2008), Demetrescu and Hanck (2012), and Herwartz et al. (2017) unit root tests (called HDH test). A brief review of all these methods is provided below:

Consider the following Panel AR model without and with the linear trend:

$$X_t = (1-\rho)\mu + \rho X_{t-1} + e_t \tag{1}$$

$$X_t = \mu + (1-\rho)\sigma_t + \rho X_{t-1} + e_t \tag{2}$$

Where $X_t = (X_{it}\cdots, X_{Nt})'$, $X_{t-1} = \left(X_{i,t-1}\cdots, X_{N,t-1}\right)'$ and $e_t = (e_{it}\cdots, e_{Nt})'$ are $N \times 1$ vectors, and e_t is heterogeneously distributed with zero mean and covariances Ω. Equation (1) has been used to test the panel unit root with the intercept only by setting the null $\rho = 1$ against the alternative $\rho < 1$ of a stationary process. On the other hand, equation (2) assumes a time trend. Applying a white-type covariance estimator, Herwartz and Sidenburg (2008) propose the following unit root test:

$$\text{tHS} = \frac{\sum_{t=1}^{T} X'_{t-1}\Delta X_t}{\sqrt{\sum_{t=1}^{T} X'_{t-1}\widehat{e}_t\widehat{e}'_t X_{t-1}}} \xrightarrow{d} N(0,1) \tag{3}$$

$$\widehat{e}_t = \Delta X_t = e_t$$

Using the 'Cauchy' estimators,[22 and 3] Demetrescu and Hanck [15] propose the following methods:

$$\text{tDH} = \frac{\sum_{t=1}^{T} sgn(X_{t-1})'\Delta X_t}{\sqrt{\sum_{t=1}^{T} sgn(X_{t-1})'\widehat{e}_t\widehat{e}'_t sgn(X_{t-1})}} \xrightarrow{d} N(0,1) \tag{4}$$

where sgn (.) indicates the sign function.

Herwartz et al. (2017), after accounting for time trend, proposed the following test:

$$\text{tHMW} = \frac{\sum_{t=2}^{T}(\widehat{X}'_{t-1}\Delta X^{*}_{t} - \widehat{v}_t)}{\widehat{s}} \tag{5}$$

Where the estimator of v_t and the variance components are based on the estimation of the traces of the covariances matrices Ω. While t_{HS} and t_{DH} tests are robust when the series contains only intercept, and t_{HMW} is robust with time trend only.

4.2.2. Cointegration test

In the second step, the study examines the long-run relationship between CO2 or EPF and regressors using the error correction model proposed by Westerlund (2007). For this purpose, the study uses the following dynamic model:

$$DCO2_{it} = \theta'_i d_t + \pi_i(CO2_{i,t-1} - \mu'_i PREM_{i,t-1} - \delta'_i X_{i,t-1}) + \sum_{j=1}^{mi}\gamma_{ij} DENV_{i,t-j} + \sum_{j=0}^{mi}\lambda \text{ij} DPREM_{i,t-j} + \sum_{j=0}^{mi}\rho \text{ij}\ DX_{i,t-j} + e_{it} \tag{6}$$

Where π is the error correction term, m is the lag order, and X is the other control variables that affect CO2. π should be significantly negative to confirm the presence of cointegration. Four-panel tests, two between-panel (P_a and P_t) and two within-panel (G_a and G_t) are developed to test cointegration using the null H_0: $\pi_i = 0$, H_a: $\pi_i = \pi < 0$ at least for some i.[2]

4.2.3. Panel ARDL model

The panel ARDL model initially developed by Pesaran and Shin (1995) and Pesaran et al. (1999), Chudik and Pesaran (2015) is suitable for panel data when time dimensions dominate the cross-section dimension with a mixture of I (0) or I (1) series.

To examine the relationship between remittances and CO2, the following model is used:

$$CO2_{it} = a_0 + b_1 PREM_{it} + b_2 MTD_{it} + b_3 PENG_{it} + b_4 PFDI_{it} + b_5 FD_{it} + \delta_i + g_t + e_{it} \tag{7}$$

Where CO2 is per capita CO2 emission, MTD is the merchandise trade (% of GDP), PREM is the per capita remittances, PENG is the per capita energy consumption (equivalent of kg. of oil), PFDI is the per capita foreign direct investment, FD is the bank credit to the domestic sector (% of GDP), γ_t is the time effect, δ_i is the country-specific fixed effect, and e_{it} is the error term. The coefficient of remittances (β_1) is the interest of the study and can be negative if remittances are used for the production and consumption of environmentally friendly products. On the other hand, if $\beta_1 > 0$, remittances degrade environmental quality in multiple ways. Similarly, FDI can augment or reduce pollution depending on its impact on the host country. If it increases production or transfers of dirty industries, it will enhance CO2 emissions in the host country. On the other hand, FDI will have a favourable effect if it transfers green or advanced technology. The coefficient of merchandise trade (β_2) can be negative or positive whether the country exports and imports advanced technology and cleaner or dirty goods (Salam and

[2] For more on 'Cauchy' estimators, see So and Shin (1999).

Table 2
Heteroscedasticity adjusted Panel Unit Root Results.

Series	t_{HS} level C	C & T	F.D. C	t_{DH} level C	C & T	F.D. C	t_{HMW} level C & T	F.D C & T	Results	CD Test
CO2	0.32	0.63	−2.09*	0.99	−0.98	−2.16*	0.52	−1.69*	I (1)	−16.45**
EPF	2.05	0.38	−2.19*	1.92	0.28	−1.69*	0.87	−1.99*	I (1)	−12.67**
PFDI	0.45	−0.82	−2.9**	0.41	−1.30	−2.15*	−0.69	−1.55*	I (1)	−2.63*
MTD	−1.72*	−1.09	–	−0.67	−0.29	–	−1.89*	–	I (0)	−1.46
PREM	0.81	1.31	−2.23*	1.78	1.31	−1.47	1.69	−1.56*	I (1)	−17.16**
PENG	0.32	−0.73	−2.52*	0.47	−0.87	−2.18*	−1.21	−2.43*	I (1)	−13.86**
FD	2.36	0.32	−2.6**	2.37	1.18	−1.69*	0.58	−1.32	I (1)	−4.35*

** $p < 0.01$ * $p < 0.05$. C-intercept, C&T-intercept with time trend, and F.D. is the first difference. BIC criterion is used to select the lag length. CD test- Pesaran (2015) cross-section dependency test.

Chishti, 2022). The coefficient of financial development (β_5) can be negative or positive. If financial development promotes pollution efficiency technologies (technology effect), it will have a favourable impact. In contrast, it will increase pollution if financial development boosts the consumption and production of pollutive and energy-intensive products (through the scale effect).

The ARDL error correction representation of equation (7) can be written as:

$$DCO2_{it} = \alpha_{0i} + \rho_i(CO2_{it-1} - \beta_{1i}PREM_{t-1} - \beta_{2i}MTD_{t-1} - \beta_{3i}PENG_{t-1} - \beta_{4i}PFDI_{t-1} - \beta_{5i}FD_{t-1}) + \sum_{j=1}^{p-1}\mu_{ij}DCO2_{i,t-j} + \sum_{i=1}^{n-1}\mu_1 DPREM_{t-i} + \sum_{i=1}^{n-1}\mu_2 PMTD_{t-i} + \sum_{i=1}^{n-1}\mu_3 DMTD_{t-i} + \sum_{i=1}^{n-1}\mu_4 DPENG_{t-i} + \sum_{i=1}^{n-1}\mu_5 DPFDI_{t-i} + \sum_{i=1}^{n-1}\mu_6 DFD_{t-i} + \sigma_i + u_{it} \quad (8)$$

Where ρ_i is the error correction term representing the co-integration and the speed of adjustment, and p and n represent the lag order. The coefficient should be significantly negative to confirm the presence of cointegration. β_i and μ_i represent the long and short-run coefficients, respectively.

4.2.4. Non-linear panel ARDL model

The symmetric ARDL model (equation (8) does not consider asymmetric or non-linear effects. Following Shin et al. (2014), equation (8) can be revised to incorporate the asymmetric impact:

$$DCO2_{it} = \alpha_{0i} + \rho_i(CO2_{it-1} - \beta^{+}_{1i}PREM^{+}_{t-1} - \beta^{-}_{2i}PREM^{-}_{t-1} - \beta_{3i}MTD_{t-1} - \beta_{4i}PEC_{t-1} - \beta_{5i}PFDI_{t-1} - \beta_{6i}FD_{t-1}) + \sum_{j=1}^{m-1}\mu_{ij}DCO2_{i,t-j} + \sum_{i=1}^{n-1}\mu^{+}{}_1 DPREM^{+}{}_{t-i} + \sum_{i=1}^{n-1}\mu^{-}{}_2 DPREM^{-}{}_{t-i} + \sum_{i=1}^{n-1}\mu_3 PMTD_{t-i} \sum_{i=1}^{n-1}\mu_3 PMTD_{t-i} + \sum_{i=1}^{n-1}\mu_4 DMTD_{t-i} + \sum_{i=1}^{n-1}\mu_5 DPEC_{t-i} + \sum_{i=1}^{n-1}\mu_6 DFDI_{t-i} + \sum_{i=1}^{n-1}\mu_7 DFD_{t-i} + \sigma_i + u_{it} \quad (9)$$

Where ρ_i is the asymmetric error correction term that captures the long-run equilibrium, m, and n represent the lag orders, respectively. $PREM^{+}$ and $PREM^{-}$ are asymmetric shocks (the positive and negative) of remittances. The sum of $\sum_{i=1}^{n-1}\mu^{+}{}_1$ estimates the short-run effect of remittances increase, and the sum of $\sum_{i=1}^{n-1}\mu^{-}{}_2$ estimates the short-run effect of a possible decrease in remittances. Thus, remittances have two components, which are the partial sum of the variables:

$$PREM^{+} = \sum_{j=1}^{t} DPREM^{+}{}_j = \sum_{j=1}^{t} Max^{+}{}_j(DPREM_j, 0) \quad (10)$$

$$PREM^{-} = \sum_{j=1}^{t} DPREM^{-}{}_j = \sum_{j=1}^{t} Min^{-}{}_j(DPREM_j, 0) \quad (11)$$

The Wald test with the null hypothesis of $\beta_1^{+} = \beta_2^{-}$ is applied to estimate the long-run asymmetric effect. Similarly, the short-run asymmetric effect is obtained using the Wald test with the null hypothesis as $\mu_1^{+} = \mu_2^{-}$.

Table 3
Cointegration Test Results.

	Dependent Variable: CO2 C	C and T	Dependent Variable: EPF C	C and T
Panel Tests	Test Values	Test Values	Test Values	Test Values
G_t	−2.34	−2.36	−3.12*	−2.98*
G_a	−12.45*	−15.67*	−14.31*	−14.21*
P_t	−7.66*	−6.88*	−8.02**	−9.32**
P_a	11.93*	−13.69*	−17.87**	21.56**

** $p < 0.01$ * $p < 0.05$. The cointegration regression is fit with one lag, one lead, and two lrwindow.

Table 4
Asymmetric Impact of Remittances on Environment Quality (CO2).

Variables	MG	PMG	CCEMG	CCEPMG
Long-run Coefficients				
MTD	0.001* (2.12)	0.002* (2.32)	0.006* (2.62)	0.003* (2.98)
PFDI	−0.002* (-2.13)	−0.003* (-2.56)	−0.003* (-2.32)	−0.002* (-2.18)
$PREM^{+}$	0.002** (3.04)	0.0021** (3.43)	0.0032* (2.57)	0.0035* (2.45)
$PREM^{-}$	0.0018* (2.76)	0.0036* (2.34)	0.0047** (3.40)	0.0053** (3.74)
PENG	0.016** (5.12)	0.02** (8.67)	0.016** (3.24)	0.025** (3.17)
FD	0.005* (2.68)	0.005** (3.88)	0.003* (2.66)	0.003* (2.89)
Short-run Coefficients				
DMTD	−0.001* (-2.11)	−0.002* (-2.56)	0.004* (2.12)	−0.002* (-2.08)
DPFDI	0.001 (0.85)	0.001* (1.99)	0.004 (1.32)	−0.003 (-1.09)
$DPREM^{+}$	−0.001 (-1.26)	−0.001 (-0.79)	−0.003 (-1.53)	−0.002 (-1.53)
$DPREM^{-}$	0.001 (-1.65)	0.001 (1.71)	−0.001 (-1.23)	0.002 (1.66)
DPENG	0.003 (1.31)	0.008* (2.17)	0.004* (1.98)	0.003* (2.66)
DFD	−0.002* (-2.16)	0.0017* (-1.96)	−0.005 (-1.45)	−0.002* (-2.21)
Diagnostic Statistics				
ECT term	−0.35** (-4.09)	−0.26** (-3.21)	−0.42** (-5.22)	−0.39** (-4.46)
CD	1.85*	1.67*	0.76 (0.32)	0.38
Hausman Test		0.43		0.27
RMSE	0.031	0.023	0.01	0.00
F. Stat	0.00	0.00	0.01	0.00
Adj. R^2	58	61	0.62	0.70
W_{LR}	0.11	0.04*	0.03*	0.03*
W_{SR}	0.67	0.54	0.45	0.31
No. Observations	160	160	160	160

** $p < 0.01$ * $p < 0.05$. The figures in parentheses are t-ratios.

4.2.5. Panel causality

The panel Granger non-causality test proposed by Juodis et al. (2021) (called the JSK causality test) is carried out using the following model:

$$DCO2_{I,t} = \mu_{0,i} + \sum_{m=1}^{m} \lambda_{k,i} DCO2_{i,t-k} + \sum_{m=1}^{m} \lambda_{k,i} DPREM_{i,t-k} + e_{i,t} \quad (12)$$

Where the parameter $\mu_{0,i}$ represent the individual fixed effect, $\lambda_{k,i}$ are the heterogeneous autoregressive parameters, m is the lag length, and $\lambda_{k,i}$ are heterogeneous feedback coefficients. Assuming homogenous lags for both $DCO2_{i,t}$, $DPREM_{i,t}$, granger causality from $DPREM_{i,t}$ to $DCO2_{i,t}$ is tested using the null hypothesis:

$$H_0 : \rho_{ki} = 0 \text{ for all i and k.}$$
$$\text{And the alternative : } H_a : \rho_{ki} \neq 0 \text{ for some i and k.}$$

The pooled estimator $\{\lambda_{ki}\}_{i=1}^{N}$ are subject to Nickel Bias corrections and form the basis of a Wald test for Granger causality. As N and T → ∞ with N/T → u^2 ∊ [0, ∞], the standard Wald statistics computed as:

$$\widehat{W}_{HPJ} = NT\widetilde{\lambda}^{'}\left(\widehat{J}^{-1}\widehat{V}\widehat{J}^{-1}\right)^{-1}\lambda \rightarrow \chi^2(K) \quad (13)$$

Where $\widehat{J} = (NT)^{-1}\sum_{i}^{1} DPREM^{'} M_{z_i} DPREM$, V is the variance and co-variances matrix.

5. Results and discussion

5.1. Results of panel unit root test

Analysis of the study begins by checking the order of the integration of the variables. Before we present the unit root results, variables are checked for cross-section effects using the Pesaran (2015) cross-section dependency (CD) test. Results confirm the presence of cross-section effects in the variables. Therefore, the application of the HDH unit root test is appropriate. As mentioned earlier, Herwartz and Sidenburg (2008) and Demetrescu and Hanck (2012) tests are robust with intercept only, whereas Herwartz et al. (2017) test is robust with time trend only. The results of both specifications (intercept and intercept with trend) are presented in Table 2.

Results suggest that variables such as CO2, EPF, PFDI, PREM, PENG, and FD are non-stationary or I (1) series, whereas MTD is stationary. This implies that we have a mixture of I (1) and I (0), and more importantly, none of the series are found in I (2). So, we can carry out the NARDL model.

Having examined the stationary properties of the variables, the cointegration relationship is established using the Westerlund (2007) cointegration test. The results with two specifications, intercept, and intercept with time trend, are presented in Table 3. Results indicate that out of four tests, at least three tests reject the null of no cointegration when the dependent variable is CO2. On the other hand, when the dependent variable is replaced with EPF, all four tests reject the null, suggesting the presence of cointegration.

5.2. Asymmetric impact of remittances on the environment

In the third step, the panel ARDL model is applied using the Pool Mean Group (PMG) and Mean Group (MG) estimator to examine the asymmetric dynamic relationship between remittances and environmental degradation. For this purpose, the remittances are decomposed into positive and negative shocks. While the MG estimator assumes both long-run and short-run coefficients to be different across countries, the PMG estimator assumes slope homogeneity in the long run.[33] The Hausman test is used to select between PMG and MG estimators by setting the null of slope homogeneity. The results of the asymmetric response of CO2 emission to changes in remittances are presented in Table 4. Results indicate that the error correction term is negative and significant at a 1 % level, confirming the presence of a long-run relationship between CO2 emission and its determinants. The coefficient of error correction terms is −0.35 and −0.26 for the MG and PMG models, respectively, indicating a 35 % and 26 % adjustment toward the long-run equilibrium for the two models. The Hausman test favours the PMG estimators as the null of slope homogeneity is not rejected, suggesting that the PMG estimators are more efficient than MG estimators for modeling the CO2 emission-remittances nexus. Therefore, we will only discuss the PMG results.

The long-run coefficients of $PREM^{+}$ and $PREM^{-}$ are positive and significant, indicating that a rise in remittances exacerbates environmental pollution, and a decrease in remittances improves ecological pollution. The coefficient of positive shocks of remittances is 0.021, suggesting that a 10 % rise in per capita remittances would lead to a 0.2 % increase in pollution level. On the other hand, a 10 % fall in per capita remittances would lead to a 0.36 % reduction in pollution. This suggests a differential impact of remittance shocks on CO2 emission. The Wald test suggests an asymmetric relationship exists between remittances and CO2 emission in the long run. The results are in line with previous studies (Ahmad et al., 2023; Khan et al., 2020; Akinlo, 2022) but in contrast to those (Usama et al., 2020; Wang et al., 2021; Islam, 2022;

[3] The PMG estimators allows the short-run coefficients to vary owing to various economic shocks.

Table 5
Asymmetric Impact of Remittances on Environment Quality (EPF).

Variables	MG	PMG	CCEMG	CCEPMG
Long-run Coefficients				
MTD	0.002 (1.04)	0.0026** (4.34)	0.001 (1.76)	0.002* (2.41)
PFDI	−0.003* (-2.51)	−0.012* (-2.33)	−0.001 (-1.86)	−0.001* (-2.79)
PREM^{+}	0.002** (2.74)	0.0022** (2.54)	0.0028* (2.85)	0.0036* (2.79)
PREM^{-}	0.0023* (2.68)	0.0033*(3.06)	0.0045** (3.11)	0.0053** (3.54)
PENG	0.004** (3.89)	0.006**(7.34)	0.005** (3.12)	0.008** (3.51)
FD	0.004*(2.45)	0.002*(2.78)	0.003* (2.88)	0.003* (2.76)
Short-run Coefficients				
DMTD	0.002 (1.55)	−0.003* (-2.66)	−0.002* (-2.19)	−0.001* (-2.09)
DPFDI	0.001 (0.98)	0.001* (2.78)	0.002* (2.07)	0.003* (2.23)
DPREM^{+}	0.001 (1.27)	0.001 (1.18)	0.002 (0.53)	0.0033* (2.13)
DPREM^{-}	−0.001 (-1.05)	0.001 (1.55)	0.002 (1.09)	0.0021* (2.66)
DPENG	0.005* (2.57)	−0.005 (-1.57)	0.004* (2.45)	−0.003 (-1.43)
DFD	−0.002* (-2.36)	−0.002* (-2.04)	−0.001 (-1.08)	−0.002 (-1.65)
Diagnostic Statistics				
ECT term	−0.56** (-6.67)	−0.41** (*-3.11)	−0.61** (-6.09)	−0.43** (-3.07)
CD	1.65*	1.69*	0.99	0.86
Hausman test		0.21		0.19
RMSE	0.016	0.013	0.01	0.021
F. Stat	0.00	0.00	0.00	0.00
Adj. R^2	57	51	0.58	0.59
W_{LR}	0.23	0.04*	0.02*	0.01*
W_{SR}	0.51	0.57	0.45	0.04
No. of Obs.	145	145	145	145

** $p < 0.01$ * $p < 0.05$. Figures in brackets are t-ratios.

Elbatanony et al., 2021; Zafar et al., 2022). As the literature suggests, remittances increase environmental pollution by increasing the consumption and production of energy-intensive products (Khan et al., 2020; Jiang et al., 2020; Akinlo, 2022). This is the case in South Asia, as suggested by previous studies (Sahoo et al., 2014; Rahman et al., 2023). Since the early 1990s, South Asia has experienced a consumption boom fuelled by remittance inflows and the availability of easy credit provided by the financial sector. This has led to rising pollution levels in South Asia (Rahman et al., 2020).

Besides remittances, other variables such as energy consumption, manufacturing trade, and financial development are found to degrade the environment. The effect of energy consumption is positive and significant, suggesting that energy consumption is the major source of CO2 emission in South Asia. South Asian countries heavily depend on traditional energy sources such as coal-fired plants, the major cause of CO2 emission. Therefore, there is a need for a transition to other sustainable sources to reduce CO2 emissions. As predicted by theoretical literature, financial development is also found to have a significant positive impact on environmental pollution in South Asia. Financial development intensifies environmental degradation by providing credit to the consumer to purchase durable products like automobiles, TVs, fridges, washing machines, etc. Results support the scale effect of financial development (Agrawal et al., 2011; Chowdhury, 2016). Most South Asian countries have experienced a consumption boom led by remittance inflows and easy availability of credit provided by the financial sector since the early 1990s (Sahoo et al., 2014). This has a significant degradation effect on the environment. Further, financial development also degrades the environment by providing credit to industry for producing dirty goods.

The coefficient of FDI is negative, indicating that FDI promotes

Table 6
Results of JSK Panel Granger Non-Causality Test.

Direction of Causality	Test Statistics	Test Value
Bi-variate Framework		
DPREM^{-} → DCO2	$\widehat{W}_{HPJ}$	32.69**
DCO2 → DPREM^{-}	$\widehat{W}_{HPJ}$	2.11
Multi-variate Framework		
DPREM^{-} → DCO2	$\widehat{W}_{HPJ}$	26.44**
DCO2 → DPREM^{-}	$\widehat{W}_{HPJ}$	1.65
Bi-variate Framework		
DPREM^{+} → DCO2	$\widehat{W}_{HPJ}$	15.44**
DCO2 → DPREM^{+}	$\widehat{W}_{HPJ}$	1.22
Multi-variate Framework		
DPREM^{+} → DCO2	$\widehat{W}_{HPJ}$	23.88**
DCO2 → DPREM^{+}	$\widehat{W}_{HPJ}$	1.44
Bi-variate Framework		
DPREM^{-} → DEPF	$\widehat{W}_{HPJ}$	66.89**
DEPF → DPREM^{-}	$\widehat{W}_{HPJ}$	7.21*
Multi-variate Framework		
DPREM^{-} → DEPF	$\widehat{W}_{HPJ}$	89.17**
DEPF → DPREM^{-}	$\widehat{W}_{HPJ}$	4.43
Bi-variate Framework		
DPREM^{+} → DEPF	$\widehat{W}_{HPJ}$	12.98**
DEPF → DPREM^{+}	$\widehat{W}_{HPJ}$	6.04*
Multi-variate Framework		
DPREM^{+} → DEPF	$\widehat{W}_{HPJ}$	16.25**
DEPF → DPREM^{+}	$\widehat{W}_{HPJ}$	6.77*

** $p < 0.01$ and * $p < 0.05$. The optimal lag length is selected based on BIC criteria.

environmental quality, confirming the pollution halo hypothesis. The negative impact of FDI may be attributed to two reasons: first, the services sector attracts the most FDI in South Asia, and second, within the manufacturing sector, most FDI goes to non-polluting industries like telecommunication, electrical equipment and food processing sector (Sahoo et al., 2014). The results of this study are in line with previous studies (Gill et al., 2018; Bose and Kohli, 2018) but in contrast to the findings of Rahaman et al. (2020) and Khan et al. (2021). The impact of manufacturing trade on environmental pollution is found to be positive and significant. As mentioned, a rise in international trade promotes economic growth and increases pollution levels through its scale effect (Duodo and Mpure, 2023). The short-run coefficients indicate no significant impact of remittances (positive and negative shocks) on the environment. The Wald test suggests no short-run asymmetric relationship between remittances and CO2 emission. However, a rise in trade and financial development improves environmental quality, and FDI degrades environmental quality.

Despite the significant results provided by the PMG method, this method does not account for the cross-section effect. Ignoring the cross-section effect can lead to inconsistent parameters and incorrect inferences (Chudik and Pesaran, 2015). This is evident from the high CD value, indicating the significant cross-section effect in the error term. Alternatively, the study uses the common correlated approach (CCEPMG and CCEMG methods) proposed by Pesaran (2006) and further developed by Chudik and Pesaran (2015). Like the PMG estimator, the CCEPMG is consistent and efficient under the assumption of long-run symmetric coefficients across countries. The Hausman test is used to examine the slope homogeneity between CCEMG and CCEPMG estimators. The results of CCEMG and CCEPMG are presented in Table 5. Therefore, we will discuss CCEPMG results. The error coefficient term is negative and significant. The coefficient is 39 %, indicating that 39 % of disequilibrium in the previous year following a shock to the system converges to long-run equilibrium in the current year. The CD test shows that the cross-section effect is reduced after accounting for a common correlated effect.

As found in PMG estimations, the long-run elasticities from CCEPMG

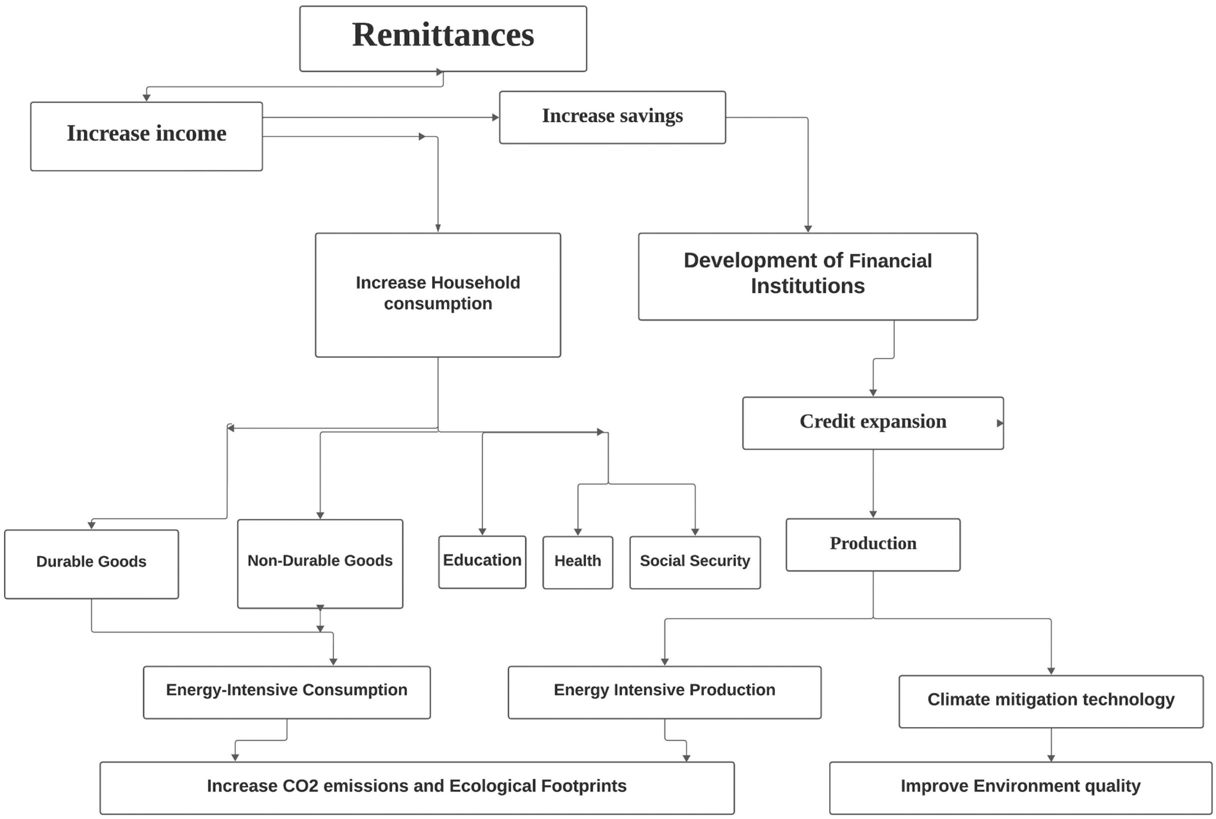

Fig. A.1. The Nexus between Remittances and the Environment.

estimators confirm the positive impact of remittances (positive and negative shocks) on environmental degradation. The coefficient of positive shock is 0.035, implying that a 10 % rise in per capita remittances escalates environmental degradation by 0.35 %. On the other hand, a 10 % fall in remittances reduces environmental pollution by 0.53 %. The Wald statistics suggest an asymmetric long-run relationship between the two as the null of homogeneity is accepted. The impact of control variables such as energy consumption, manufacturing trade, and financial development are positive and significant.

Regarding the short-run coefficients, the study finds no significant effect of remittances (both positive and negative shocks) on the environment. The Wald test suggests no significant asymmetric relationship between remittances and CO2 emission. Further, trade and financial development have a negative short-run impact, and energy consumption positively impacts CO2 emissions.

5.3. Robustness check

For the robustness of the previous results, the study uses alternative indicators of environmental degradation, the Ecological Footprint (EPF), in place of CO2 emission. The results are depicted in Table 5. Results from Table 5 demonstrate that all the explanatory variables significantly affect EPF as expected. The error coefficient term is negative and significant, suggesting the presence in the long run. The Hausman test shows that PMG and CCEPMG are efficient. So, we discuss only the results of PMG and CCEPMG estimators. The coefficient of remittances (positive and negative shocks) is positive, indicating that positive shocks adversely impact environmental quality, and the reverse improves the same. A 10 % rise in remittances leads to 0.20 % and 0.36 % increase in EPF in both estimations. Conversely, a 10 % fall in remittances was accompanied by 0.45 and 0.53 % improvement in environmental quality, respectively.

The short-run coefficients indicate that a positive shock in remittances increases environmental degradation, and a negative shock in remittances improves the same. Also, in the short run, the Wald test confirms the asymmetric relationship between remittances and environmental degradation (see Appendix Fig. A.2). So, the study reached a similar conclusion by using alternative measures of environmental qualities, as in the case of CO2 emission.

5.4. Evidence of panel causality

Finally, the causality analysis is carried out using the JSK panel Granger non-causality test in the last part of our empirical analysis. To address non-linearity, the study conducts panel causality between $DPREM^{+}$ and DCO2 and $DPREM^{-}$ and DCO2. The results are presented in Table 6. It is observed that there exists unidirectional causality from a rise in remittances ($DPREM^{+}$) or a fall in remittances ($DPREM^{-}$) to environment quality (DCO2) both in a bi-variate and in a multivariate framework. The null of no causality from an increase or decrease in remittances to CO2 is rejected at a 1 % level, implying that a rise in remittances causes environmental degradation and a fall in remittances improves environmental quality in South Asia.

Additionally, the causality between remittance ($DPREM^{+}$ and $DPREM^{-}$) and DEPF was also examined for robustness check. The results suggest a bi-directional causality between remittances (positive and negative shocks) and environment quality (EPF) in a bivariate and multivariate framework. Therefore, causality evidence supports an asymmetric link as a rise in remittances degrades the environment, and a fall in remittances reduces the pollution level in South Asia. The causality results support an asymmetric relationship between the two.

6. Conclusion and policy implications

Remittances are a catalyst for South Asian countries as they promote economic growth and development and are critical for achieving SDGs.

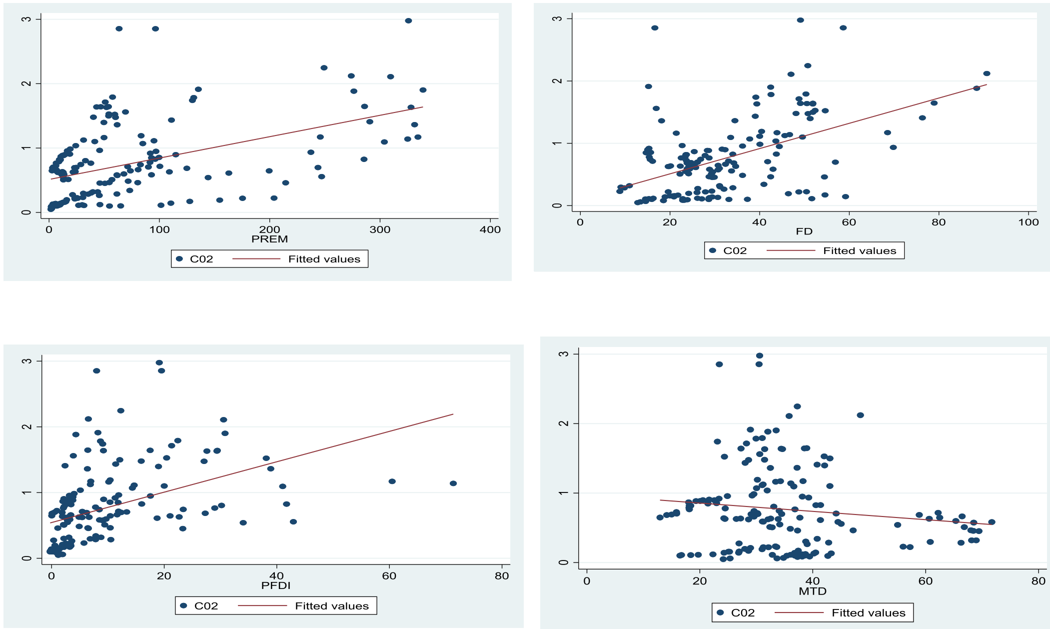

Fig. A.2. Bi-variate relationship between CO2 and explanatory variables.

However, they have been found to damage the environment, which could undermine SDGs. Therefore, this study investigates the remittances and environment linkage using a panel of five South Asian countries from 1991 to 2021. The study employs second-generation unit root, cointegration, causality, and non-linear panel ARDL models to account for endogeneity and cross-section effects for this goal. Several other control variables are included in the model to avoid omission bias problems. The study used two indicators of environmental quality, CO2 emission and Ecological Footprint, to derive robust results.

The results of this study suggest that variables are mixed in nature with the combination of the I (1) and I (0) series; hence, the panel ARDL model is appropriate. The cointegration test confirms the long-run stable relationship between remittances and environmental quality. When CO2 is used for environmental quality, the results show a long-run asymmetric link between the two, implying that positive shocks in remittances exacerbate environmental degradation. In contrast, the negative shocks have the opposite effect. Similarly, the study finds both long and short-run asymmetric effects of remittance when CO2 is replaced with EPF. The causality results further support the asymmetric link between remittances and the environment as a unidirectional causality running from remittances ($DPREM^{+}$ and $DPREM^{-}$) to the environment. All the control variables are found to exacerbate environmental degradation except FDI, which has a favourable effect on the environment.

In light of the above findings, the study recommends a multiple strategies should be followed. In this context, the following policies need to be implemented to neutralize or reduce their negative impact: First, subsidies/incentives should be given to the industry to encourage the production of environmentally friendly products. Subsidies/incentives should be doled out to consumers to encourage shifting from energy-intensive products to energy-efficient and environmentally friendly products. Efforts should be undertaken to promote energy efficiency at the industry level as well as at household levels. Steps should be undertaken to increase renewable energy production and consumption by taxing fossil energy and subsidizing renewable energy. Incentives should be provided to encourage innovation in green technology. FDI should be directed to an industry producing energy-efficient and environment-friendly products. Regulatory frameworks such as environmental standards should be improved to reduce the adverse environmental impact. Environmental awareness should be increased by involving citizens, NGOs, schools, and colleges using public and private channels. Education policy should be re-framed by including a curriculum on environmental sustainability. In this context, the New Education Policy (NEP), 2020, introduced by India, is a significant step. An integrated approach combining the development and environmental goals should be followed by increasing investment in clean energy and green technology.

In the end, we would like to point out a few limitations of this study. The current study is limited to South Asian countries; similar studies can be extended to other developing countries. Further, the study can be extended by examining the differential environmental impact conditioned on economic development. The role of the institution can be investigated in the interplay between the two.

CRediT authorship contribution statement

Ranjan Kumar Dash: Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Deepa Jitendra Gupta:** Writing – review & editing, Writing – original draft, Validation, Conceptualization, Formal analysis, Data curation. **Niharika Singh:** Conceptualization, Data curation, Methodology, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

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