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Are remittances an opportunity or a threat to sustainable environmental quality in India? Evidence from nonlinear smooth transition models

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Abstract

The inflow of remittances is a major source of external financing for developing countries and play a crucial role in economic welfare. It is also associated with environmental degradation, despite its stimulating effects on industrial production, aggregate demand, savings and investments. This study inspects the impact of remittances on environmental quality in India using non-linear time series methods covering the period 1975 to 2022. Ecological footprint is used as an indicator of the quality of the environment to investigate the relationship between remittances inflows, GDP per capita, net FDI inflows and financial development. Asymmetric smooth transition models allowing nonlinearity and structural breaks are used to depict the relationship between the variables. The empirical results show that remittance inflows, financial development and economic growth contribute environmental pollution and deteriorate environmental quality in the long and short term. Based on the results, it is recommended to use remittances in India as a useful policy instrument to support the demand for energy efficient products and environmentally friendly investments.

Keywords Remittances · Ecological footprint · Asymmetric ESTAR cointegration · Financial development · India

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Introduction

Remittances have become an important part of global capital flows and have been an important source of external financing for low- and middle-income countries since 2015 (KNOMAD, 2022: 1). According to the World Bank, remittances reached $719 billion in 2019, up from $126 billion in 2000. However, global remittances fell to $711 billion in 2020 due to increased anti-immigrant rhetoric and policies in some countries, tax policies or similar restrictions that discourage the hiring of foreign workers, and the impact of the COVID-19 pandemic. Remittance flows to low- and middle-income countries (LMICs) are projected to grow 10.2% to $597 billion in 2021. Remittances are estimated to grow 4.9 percent to $626 billion by 2022. Remittances will thus become an even larger source of external financing for LMICs in 2022 than foreign direct investment, official development aid and portfolio investment flows.

The top five recipients of remittances among low- and middle-income countries in 2022 are expected to be India, Mexico, China, the Philippines and Egypt (Fig. 1). India continues to receive the most, around $83 billion, despite global remittances falling during the COVID-19 pandemic. This is higher than the total GDP of some countries and is a record compared to other remittance-receiving countries. It is expected that remittances to India will reach $100 billion in 2022. Such high capital flows have increased the importance of remittances in developing economies like India. It has prompted economists and policy makers to examine the social, economic and environmental impacts of remittances.

The inflow of remittances affects the quality of the environment through many different channels. Acharya and Leon-Gonzales (2012), Kadozi (2019), Giuliano and Ruiz-Arranz (2005), Nsias and Fayissa (2013), Adekunle et al. (2021), Ahmad et al. (2022) imply that remittances increase the disposable income of many

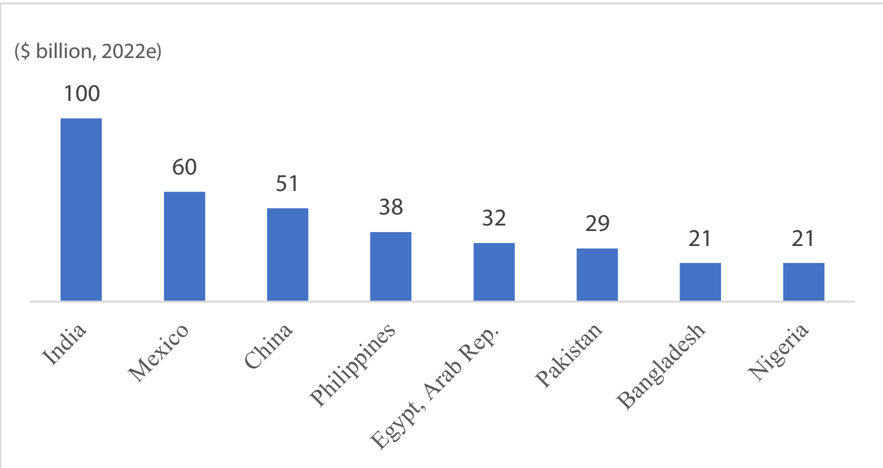

Fig. 1 Top Recipients of Remittances among Low- and Middle-Income Countries. Source: KNOMAD (2022). Remittances Brave Global Headwinds. Special Focus: Climate Migration and Development Brief 37, November 2022

households, giving them access to consumption and investment goods that they could not afford. The growing demand for capital goods and consumer durables financed by remittances tends to pollute the environment (Ahmad et al., 2022; Karasoy, 2021; Zafar et al., 2022). Furthermore, remittances support poverty alleviation by providing low-income individuals with capital to start new businesses (Itoo & Ali, 2023; Khan et al., 2022; Qingquan et al., 2020). The increase in capital accumulation and investments triggers GDP growth and harms environmental quality (Sorensen et al., 2002; Ahmad et al., 2022; Chishti, 2022).

Remittances inflows will make individuals more likely to save and accumulate. The increase in savings will also contribute to financial development by leading to an expansion of bank deposits (Majeed et al., 2020; Neog & Yadava, 2020; Wang et al., 2021; Yang et al., 2021). The increase in consumption and the expansion of credit facilities will also have an impact on industrial production (Akinlo, 2022; Dong et al., 2020). Environmental quality is likely to deteriorate as a result of all these interactions (Khan et al., 2022; Rahman et al., 2023).

There is a fairly large body of empirical literature examining the determinants of environmental degradation such as economic growth, foreign direct investment (FDI), financial development, urbanization and energy consumption. However, the environmental impact of remittances has only begun to be studied in recent years, and the number of empirical studies is very limited. The objective of this study is to examine the impact of remittances on ecological footprint in India, the largest recipient of remittances. To the best of our knowledge, there are only three studies in the literature that examine the impact of remittances for India using linear and nonlinear ARDL methods (Itoo & Ali, 2023; Neog & Yadava, 2020; Villanthenkodath & Mahalik, 2022). This study is a contribution to the literature as it is the first study to examine the impact of remittances on environmental quality in India using asymmetric smooth transition models that consider structural breaks and nonlinear structure together. In addition to a methodological contribution to the existing literature, this study examines the relationship between remittances and environmental degradation with a more comprehensive indicator of environmental quality. Most studies on India use carbon emissions as a proxy of environmental degradation (e.g. Itoo & Ali, 2023; Neog & Yadava, 2020; Villanthenkodath & Mahalik, 2022). However, this study aims to provide more precise policy recommendations for India using ecological footprint as environmental quality indicator. Lastly, Fourier-Shin cointegration test propounded by Tsong et al. (2016) is applied in order to confirm the robustness of the findings.

The study is organized as follows: Sect. 2 presents the theoretical framework and the literature review. Section 3 explains the model, dataset and empirical model. Section 4 explains the methodology and Sect. 5 evaluates empirical findings. Section 6 represents discussion and policy implications**.** The paper concludes with a summary of the findings and policy suggestions.

Theoretical Framework

Remittances, especially in developing and underdeveloped countries, are one of the capital flows that have positive impact on balance of payments, poverty and income distribution. Many studies show that remittances support economic growth through savings, consumption and investment in human and physical capital (Adams & Page, 2003; Acosta et al., 2007; Giuliano & Ruiz-Arranz, 2005; Nsias and Fayissa, 2013; Cazachevici et al., 2020; Adekunle et al., 2021; Ahmad et al., 2022). Remittances are considered as a major factor in poverty alleviation, as well as a source of financial capital that facilitates the creation of small businesses by poor families (Acharya & Leon-Gonzales, 2012; Ghosh, 2006; Rosser, 2008; Sorensen et al., 2002; Chishti, 2022; Itoo & Ali, 2023). There is a flourishing literature examining how remittances relate to many macroeconomic variables. However, there is a limited number of studies on the potential impact of remittances on the environment. Remittances can directly and indirectly affect environment through consuming, investing and saving.

The first direct impact of remittances on the environment is through consumption, as they increase both households' disposable income and the amount of savings. Higher disposable income allows many households to purchase consumer and investment goods such as new cars, appliances (computers, air conditioners, electrical appliances, etc.) and housing that would otherwise be unaffordable. This will increase demand for energy, particularly through demand for electrical machinery and housing (Adekunle et al., 2021; Ahmad et al., 2022; Itoo & Ali, 2023; Khan et al., 2022; Qingquan et al., 2020; Zafar et al., 2022).

Remittance flows also have an impact on environment through investments. Remittances encourage household entrepreneurship, investment and risk-taking by providing a reliable and stable source of income. On the other hand, according to Barajas et al. (2009), Singh et al. (2010), Rahman et al. (2023) and Itoo and Ali (2023), remittances stimulate investment efforts by neutralizing high macroeconomic volatility. The establishment of new companies or the expansion of the capacity of existing companies will have a negative impact on energy demand and environmental degradation (Neog & Yadava, 2020; Qingquan et al., 2020).

In addition, Li et al. (2015), Zhang (2011), Ozturk and Acaravci (2013), Jamel and Maktouf (2017), Majeed et al. (2020), Wang et al. (2021), Khan et al. (2022), Ahmad et al. (2022) find convincing evidence that financial development leads to economic development and thus to environmental pollution. The inflow of remittances through official channels via banks has a positive impact on financial development through an increase in the demand for banking products. Recipients may need the banking system to store remittances safely, even if they arrive through informal channels. Banks may also be more willing to lend to remittance recipients because remittances are a stable source of income. Each of these has an impact on the environmental degradation through economic development (Aggarwal et al., 2011; Karasoy, 2021; Yang et al., 2021). On the other hand, a number of studies suggest that financial development improves environmental quality by stimulating technological development (Adams & Klobodu, 2018; Jiang et al., 2021; Shahbaz et al., 2013; Zhao & Yang, 2020). These studies emphasis that financial development accelerates research and development (R&D) activities and provides new opportunities to increase production without degrading the environment (Frankel & Romer, 1999; Majeed et al., 2020; Neog & Yadava, 2020; Villanthenkodath & Mahalik, 2022; Wang et al., 2021; Yang et al., 2021).

Findings from studies examining the relationship between energy use, income and environmental degradation in India also vary. Alam et al. (2011) examined the causal relationship between CO2 emissions, economic growth and energy consumption in India and concluded that there is a bidirectional causal relationship between CO2 emissions and economic growth in the long run. Govindaraju and Tang (2013) examined the relationship between economic growth, coal consumption and CO2 emissions in China and India. While there is a cointegration relationship between economic growth and CO2 emissions in China, no relationship was found in the long run in India. However, the short-term results suggest that there is a bi-directional causality between economic growth and CO2 emissions. Nain et al. (2015) investigated the causal relationship between energy consumption, economic growth and CO2 emissions for the period from 1971 to 2011. Based on the findings of this study using total and disaggregated energy consumption measurements, there is a causal relationship between electricity consumption, economic growth, and CO2 emissions in the short term. Rana and Sharma (2019) examined the validity of Environmental Kuznets Curve and Pollution Haven Hypothesis (PHH) hypotheses in India. Their findings indicate that both Environmental Kuznets and PHH hypotheses are valid. Shahbaz et al. (2021) analyzed the impact of per capita income, energy use, trade openness and oil prices on the emission of CO2 in India for the period from 1980 to 2019. The results of the nonlinear autoregressive distributed lag (NARDL) approach showed that the independent variables have an asymmetric effect on CO2 emissions in the long run.

The literature on environmental degradation is dominated by the relationship between environmental quality and economic growth, industrial production, energy use, foreign direct investment, financial development and urbanization. However, there is a paucity of studies that examine the environmental impact of capital flows such as remittances and international aid. Recently, a number of researchers have started to carry out studies that examine the relationship between remittances and environmental pollution. Table 1 shows the main findings of these studies.

Model and Data Set

This study inspects the remittances have an impact on environmental quality in India using non-linear time series methods by taking time series data from 1975–2022. For this purpose, ecological footprint is used as an indicator of the quality of the environment. Ecological footprint is more comprehensive and broader proxy than carbon dioxide emissions to measure the environmental quality. The ecological footprint includes all the forest land, build-up land, grazing land, fishing grounds, carbon, and cropland, and is considered to be a more inclusive indicator of environmental quality than carbon emissions (Dash et al., 2024). Following Ahmad et al. (2019), Khan et al. (2020), Neog and Yadava (2020), Shahbaz et al. (2021), Elbatanony et al. (2021), Kibria (2021), Usman and Jahanger (2021), Yang et al. (2021), Akinlo (2022) the inflow of remittances affects the quality of the environment through many different channels. Ahmad et al. (2022), Zafar et al. (2022),

Table 1 Studies examining the relationship of remittances and the environment

Author(s)	Country/Country Group	Period	Method	Findings
Sharma et al. (2019)	Nepal	1971–2013	ARDL	Remittances and foreign aid decrease the CO_2 emissions
Ahmad et al. (2019)	China	1980–2014	NARDL	Positive shock in remittances causes an increase in CO2 emissions, while a negative shock in remittances causes a decrease in CO2 emissions
Khan et al. (2020)	BRICS Countries	1986–2016	CCEMG and FM-LS	Remittances cause environmental degradation in BRICS countries
Yang et al. (2020)	97 Countries	1990–2016	GMM	Remittances increase CO_2
Neog and Yadava (2020)	India	1980–2014	NARDL	CO_2 emissions and remittances have cointegrated positive and asymmetrical relationship in the long term
Usama et al. (2020)	Ethiopia	1981–2015	ARDL	Remittances reduce CO_2
Wawrzyniak and Doryń (2020)	93 emerging and developing countries	1995–2014	GMM	Remittances have no impact on the reduction of carbon emissions
Brown et al. (2020)	Jamaica	1976–2014	ARDL and NARDL	Remittances have a negative impact on the environment at low levels. However, positive environmental impacts emerge when per capita remittances exceed the $450 threshold
Yang et al. (2021)	Brazil, India, China, and South Africa	1990–2016	DSUR, FMOLS	Remittance inflows significantly deteriorate the environmental quality
Kibria (2021)	Bangladesh	1980–2016	NARDL	Positive and negative shocks in remittances have significant long-run effects on CO2 emissions in the same direction

Table 1 (continued)

Author(s)	Country/Country Group	Period	Method	Findings
Mahalik et al. (2021)	India	1978–2014	ARDL	Remittance inflows increase CO_2 emissions in the long term
Wang et al. (2021)	India, Philippines, Egypt, Pakistan, and Bangladesh	1980–2016	DOLS	Remittance inflows reduce CO_2 emissions
Karasoy (2021)	Philippines	1977–2016	Augmented ARDL and VECM	Remittance inflows threats environmental sustainability in the long-run both directly and indirectly through boosting income and energy consumption
Villanthenkodath and Mahalik (2022)	India	1980–2018	ARDL	Remittances inflows improve environmental quality in the long-run and degrades it in the short-run
Li et al. (2022)	China	1981–2019	ARDL	There is a positive and asymmetrical relationship between CO_2 and remittances
Akinlo (2022)	Nigeria	1980–2018	NARDL	Remittances contribute to environmental degradation in the long run
Ahmad et al. (2022)	Pakistan	1980–2018	ARDL, NARDL	Positive shock of remittances contributes to pollution emissions while the negative shock of remittances mitigates the pollution both in the short and long run
Zafar et al. (2022)	22 top remittance-receiving countries	1986–2017	Westerlund and Edgerton cointegration, CupFM and CUP-BC estimators	Remittances have reducing effects on environmental degradation

Table 1 (continued)

Author(s)	Country/Country Group	Period	Method	Findings
Rahman et al. (2023)	Six Asian Countries	1982–2014	ARDL	Although there is positive relationship between CO_2 emissions and remittances in Sri Lanka, Pakistan, Philippines and Bangladesh, there is no significant relationship in India and China
Mensah and Abdul-Mumuni (2023)	31 sub-Saharan African countries	1996–2018	Asymmetric panel ARDL	Remittances have positive and statistically significant effect on carbon emissions
Chishti (2022)	Pakistan	1976Q1-2020Q4	Partial and multiple wavelet coherence	Remittances significantly exacerbate environmental pollution by increasing their ecological footprint
Dash et al. (2024)	Five South Asian countries	1991–2021	NARDL	A rise in remittances exacerbates environmental pollution and a decrease in remittances improves ecological pollution

Villanthenkodath and Mahalik (2022), Chishti (2022), Dash et al. (2024) the empirical model can be expressed as Eq. 1.

$$EF_t = \alpha_0 + \alpha_1 GDPPC_t + \alpha_2 REMIT_t + \alpha_3 FDI_t + \alpha_4 CREDIT_t + \varepsilon_t \tag{1}$$

where $\alpha_0, \alpha_1, \alpha_2, \alpha_3, \alpha_4$ are estimated parameters, t denotes time and ε is error terms. EF is ecological footprint as a proxy of quality of the environment, REMIT is the personal remittances received (percentage of GDP) and GDP is the per capita real GDP (constant 2015 USD) as a measure of economic development. CREDIT refers to domestic credit to private sector (% of GDP) as an indicator of financial development and FDI is net foreign direct investment inflows relative to GDP. The data of EF were collected from Global Footprint Network (2022) database and the rest of the variables are obtained from the World Bank, World Development Indicators.

The graphical trends of remittances and ecological footprint after 1975 is shown in Fig. 2. The graph of the EF series shows that there has been a steady increase in ecological footprint in India. India, which has the second largest population in the world, has a negative outlook with a per capita ecological footprint of 1.19 in 2022.

The timeline of remittances shows a significant decline in the period 1980–1990. Gulf countries such as the United Arab Emirates, Saudi Arabia, Kuwait, Qatar and Oman are the largest recipients of Indian workers. The migration of Indian workers to the region was affected by the Iran-Iraq War, which lasted throughout the 1980s, and the Gulf War in the early 1990s, which had a negative impact on remittance inflows. It can be seen that remittances have increased steadily since 1990, although there were dips during the 1998, 2004 and 2008 global crises.

Methodology

Although linear time series methods are widely used in academic studies, they can be weak in the modelling of economic or structural change. In particular, analyses with non-stationary or non-linear data will lead to biased results (Zivot & Wang, 2006: 653). Possible structural breaks and nonlinearity in time series affect the power of traditional unit root tests.

Unit root tests are not effective in distinguishing the behavior of a unit root process from that of a stationary process with structural breaks. Therefore, the null hypothesis of the existence of a unit root may not be rejected by conventional unit

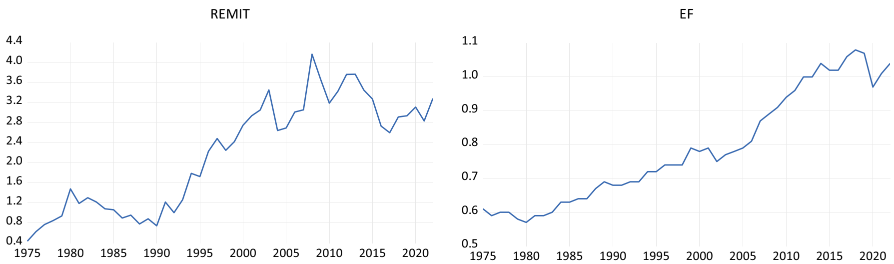

Fig. 2 The timeline of remittances and ecological footprint in the period 1975–2022

root tests such as DF, ADF (Hepsag, 2021a). Moreover, Perron (1989, 1990), Zivot and Andrews (1992), Lumsdaine and Papell (1997), Bai and Perron (2003), Lee and Strazicich (2003) assume that the structural change occurs suddenly and at some point (Cuestas & Ordóñez, 2014: 969). Based on this assumption, the structural break is accounted for by creating a dummy variable. The dummy variable is assigned a value of zero prior to the break or regime change, and thereafter it takes the value of 1. However, structural breaks or regime changes do not occur suddenly but gradually over time. Leybourne et al. (1998) define a gradual structural break using the logistic smooth transition function.

Kapetanios et al. (2003) developed the first method to account for both nonlinearity and structural breaks in unit root analysis. This method uses the exponential smooth transition autoregressive (ESTAR) model to account for nonlinearity and non-stationarity (Kapetanios et al., 2003: 360). This method calculates three test statistics for raw data, demeaned data and detrended data (Kapetanios et al., 2003: 364). The null hypothesis is the existence of a unit root and the alternative hypothesis is non-linear ESTAR stationarity.

In Eq. 2, the null hypothesis is tested with $\theta > 0$. But because γ is not defined in this regression, it is not possible to test the null hypothesis. In order to overcome this problem, Kapetanios et al. (2003) applied a Taylor expansion of the first order to arrive at the auxiliary regression model in Eq. 3.

$$\Delta y_t = \gamma y_{t-1}\left[1 - \exp(-\theta y_{t-1}^2)\right] + e_t \tag{2}$$

$$\Delta y_t = \delta y_{t-1}^3 + e_t \tag{3}$$

Equation 3 is estimated by OLS. The test statistic is calculated by $t_{NL} = \widehat{\delta} \big/ s_{\widehat{\delta}}$. The ESTAR non-linearity is represented by the term y_{t-1}^3 in the model. The null hypothesis is tested with $\delta = 0$ and the alternative hypothesis with $\delta < 0$. If the calculated t_{NL} statistic exceeds the Kapetanios et al. (2003) critical value, the null hypothesis is rejected. It is then concluded that the series is ESTAR-stationary.

In order to test the cointegration relationship between variables, several methods have been developed Engle and Granger (1987), Phillips and Ouliaris (1990), Johansen (1991, 1995). The common feature of these studies is that they assume that the adjustment to the long-run equilibrium will be linear. Hepsag (2021b) proposed a new method using the asymmetric exponential smooth transition model (AESTAR), which pays regard to the symmetrical and asymmetrical behavior of the series when returning to equilibrium. Exponential transition function and logistic transition function are shown in Eqs. 4 and 5, respectively.

$$G_t(\theta_1, u_{t-1}) = 1 - exp(-\theta_1(u_{t-1}^2))\ \theta_1 \geq 0 \tag{4}$$

$$S_t(\theta_2, u_{t-1}) = \theta_2 \geq 0 \tag{5}$$

This method follows a two-stage process. In the first step, the long-term equation is estimated with least squares method and the residuals are calculated. In the second stage, the AESTAR-ECM model in Eq. 6 is created, considering that the residuals follow an asymmetric exponential smooth transition autoregressive process.

$$\Delta y_t = G_t(\theta_1, u_{t-1})\left\{S_t(\theta_2, u_{t-1})\gamma_1 + (1 - S_t(\theta_2, u_{t-1}))\gamma_2\right\}u_{t-1} + \psi'\Delta x_t + \sum_{i=1}^{p} \omega_i'\Delta z_{t-i} + \varepsilon_t \Delta x_t = \sum_{i=1}^{p} \Gamma_i'\Delta z_{t-i} + \eta_t \tag{6}$$

The null hypothesis of no cointegration is tested with $\theta_1 = 0$, and the alternative hypothesis is tested with $\theta_1 > 0$. Since $\gamma_1, \gamma_2, \theta_2$ are not defined in the null hypothesis, it is not possible to directly test the hypothesis of no cointegration. To solve this problem, Hepsag (2021b) applied first-order Taylor expansion to the AESTAR-ECM model and reached Eq. 7 (Akkaya & Hepsag, 2021: 35098).

$$\Delta y_t = \phi_1 \hat{u}_{t-1}^3 + \phi_2 \hat{u}_{t-1}^4 + \psi'\Delta x_t + \sum_{i=1}^{p} \omega_i'\Delta z_{t-i} + v_t \tag{7}$$

After the estimation of Eq. 7, $\phi_1 = \phi_2 = 0$ the null hypothesis is tested against the alternative hypothesis with two new test statistics developed by Hepsag (2021b). While F_{ANEC} is an F-type statistic obtained from nonlinear AESTAR-ECM, F_{ANEG} was calculated in a similar way to Engle and Granger (1987) DF test statistic. There are critical values for 3 different versions of these two test statistics: raw data, demeaned data and detrended data (Hepsag, 2021b: 401–404). In the AESTAR-ECM model, the null hypothesis is no cointegration, and the alternative hypothesis is symmetric or asymmetric ESTAR cointegration. If the null hypothesis of no cointegration is rejected, the null hypothesis established as symmetrical ESTAR cointegration should be tested against the asymmetric ESTAR cointegration. The standard F test is used for this test (Akkaya and Hepsag, 2021b: 403).

Empirical Results

Brock et al., (1996-BDS) developed one of the most popular tests for detecting nonlinearity. The BDS test is based on the correlation integral. It assumes that the time series are independent and identically distributed as the null hypothesis. BDS linearity test results for all variables are reported in Table 2. The null hypothesis that the series follow a linear process is rejected for all of the variables. This indicates that

Table 2 BDS Linearity Test Results

Variables					
EF	0.176	0.294	0.380	0.425	0.449
REMIT	0.150	0.268	0.342	0.393	0.429
FDI	0.130	0.234	0.276	0.306	0.321
CREDIT	0.165	0.281	0.354	0.403	0.431
GDPPC	0.174	0.282	0.352	0.386	0397

Table 3 The results of Kapetanios et al. (2003) and ADF unit root tests

Level		First Difference	
Variables	KSS Test Statistics	Variables	ADF test statistics
EF	-0.674 (0)	ΔEF	-7.119***
REMIT	-2.229 (1)	$\Delta REMIT$	-7.714 ***
FDI	-2.713 (1)	ΔFDI	-8.063***
CREDIT	-0.916 (1)	$\Delta CREDIT$	-2.668*
GDPPC	-1.009 (1)	$\Delta GDPPC$	-4.951***

* and *** denote rejection of the null hypothesis at the 99 and 90% significance level. The optimal lag lengths are determined through AIC and maximum lag is set to 4. Values in parentheses represent the optimal lag. Kapetanios et al. (2003) critical values for Case 2 are -3.48, -2.93 and -2.66 for 1, 5, 10%, respectively

Table 4 Results of Hepsag (2021b) Cointegration Test

$F_{ANEC,\ dem}$	Lag length	F statistic	$F_{ANEC,trend}$	Lag length	F statistic
8.343*	0	10.887**	8.846*	4	16.380**

Note: For k=4, the critical values of $F_{ANEC,\ dem}$ and $F_{ANEC,\ trend}$ at the 5% significance level are 8.125 and 9.312, respectively. * indicates that the null hypothesis of no cointegration is rejected at the 5% significance level. ** shows the symmetric ESTAR null hypothesis is rejected at the 1% significance level

the variables are nonlinear. Therefore, nonlinear methods can apply in the following stages.

The basic requirement of time series modelling is to determine the order of integration level of the variables. In this study, Kapetanios et al. (2003) and Dickey and Fuller (1981) ADF unit roots test are applied to investigate the stationary property of $EF, REMIT, FDI, CREDIT, GDPPC$.

According to Table 3, Kapetanios et al. (2003) test results indicate that the null hypothesis of a unit root cannot be rejected at level. It can be noticed that ecological footprint, remittance inflows, per capita real GDP, domestic credit to private sector and FDI contain unit root problem at level. ADF test results show that the unit root problem disappears in the first difference of the series. Once detecting all variables are I(1), the asymmetric nonlinear cointegration test proposed by Hepsag (2021b) is preferred on the purpose of examining the cointegration relationship between the series.

Hepsag (2021b) cointegration test primarily investigates whether the series are cointegrated or not. The cointegration test results of this method are reported in Table 4.

According to Hepsag (2021b) cointegration test results in Table 4, the null hypothesis of no cointegration is rejected at the 5% significance level with $F_{ANEC,\ dem}$ and $F_{ANEC,trend}$ test statistics. This result shows the existence of a long-term relationship between the variables in the long run. The F test is applied to test the symmetric ESTAR cointegration against asymmetric ESTAR cointegration in the model after determining the existence of the cointegration relationship between the variables.

The null hypothesis of symmetric ESTAR cointegration is rejected at the 5% significance level according to the results in Table 4. This finding implies that positive and negative shocks have different effects in reaching equilibrium in the long run. Based on this result, the long- and short-term coefficients of the asymmetric ESTAR models are estimated using OLS and the findings are reported in Table 5.

The coefficient estimates in Table 5 indicate that remittance inflows increase ecological footprint in both long and short run for India. The coefficient of *REMIT* is 3.023, suggesting that a one-unit rise in the remittance inflow would lead to 3.023 unit increase in ecological footprint. It implies that remittance inflows have an adverse impact on environmental quality in the long-run and degrades it in the short-run. This result confirms the previous studies conducted by Ahmad et al. (2019) for China, Khan et al. (2020) for BRICS countries, Yang et al. (2020) for selected emerging and developing economies, Brown et al. (2020) for Jamaica, Karasoy (2021) for Philippines, Jiang et al. (2021) for Australia, Yang et al. (2021) for BICS countries, Kibria (2021) for Bangladesh, Li et al. (2022) for China, Akinlo (2022) for Nigeria, Ahmad et al. (2022) and Chishti (2022) for Pakistan, Rahman et al. (2023) for the Philippines, Sri Lanka, Bangladesh and Pakistan, Mensah and Abdul-Mumuni (2023), Dash et al. (2024) for five South Asian countries. Our findings are similar to Neog and Yadava (2020), Mahalik et al. (2021), Yang et al. (2021) for India. However, our results deviate from the finding of Khan et al. (2020), Wang et al. (2021), Villanthenkodath and Mahalik (2022), Itoo and Ali (2023) for India where they found that remittances help mitigate environmental degradation.

According to the long-term coefficient estimates in Table 5, it is seen that economic growth (*GDPPC*) and financial development (*CREDIT*) have statistically significant and detrimental effects on ecological footprint. The impact of financial development on environmental quality is only significant in the long term, although

Table 5 The Results of Long-run and Short-run Coefficients of Asymmetric ESTAR Models

Variables	Coefficients	t statistics	Diagnostic Tests	
Long-run estimates				
GDPPC	0.206***	8.381	$Breusch-Pagan-GodfreyHeteroskedacity$	2.378 (0.06)
REMIT	3.023***	3.072		
FDI	-0.869	-0.637	$Jarque-BeraNormality$	3.685 (0.15)
CREDIT	0.259*	1.905	$Breusch-GodfreyLM$	2.054 (0.07)
Short-run estimates				
$\Delta GDPPC$	0.0011***	6.852	$Breusch-Pagan-GodfreyHeteroskedacity$	0.718 (0.63)
$\Delta REMIT$	0.014*	1.643		
ΔFDI	-0.007	-0.979	$Jarque-BeraNormality$	2.379 (0.30)
$\Delta CREDIT$	-0.0004	-0.311	$Breusch-GodfreyLM$	0.306 (0.73)
$\hat{u}^3_{t-1}$	-176.01***	-3.386		
$\hat{u}^4_{t-1}$	-2991.8***	-3.299		

*** and * represent the significance at the 1% and 10% levels, respectively. The probability values for diagnostic tests are given in parentheses. Δ denotes first difference operator economic growth has a significant adverse effect on the ecological footprint in both the short and long term. Financial development deteriorates environmental quality in India by providing funds to purchase of consumer and capital goods. Financial development also enables investors to create new industries or expand existing ones by facilitating credit access. Similarly, economic development is a stimulus to aggregate demand and industrial production. These developments have a negative impact on the environmental quality in India as a result of the more intensive use of energy. These results are consistent with the findings of Li et al. (2015), Zhang (2011), Ozturk and Acaravci (2013), Jamel and Maktouf (2017), Majeed et al. (2020), Yang et al. (2020), Wang et al. (2021), Khan et al. (2022), Akinlo (2022), Ahmad et al. (2022), Rahman et al. (2023).

In the short run, the coefficients of remittance inflows and economic growth are significant and have detrimental impact on ecological footprint in India. The coefficient of FDI inflows is negative but statistically insignificant both in long and short term. It is also detected that financial development have no significant impact on the ecological footprint in short run in contrast to the long run.

We also check the robustness of the long run and short run estimations to examine the statistical validity of the asymmetric ESTAR model. It was performed some diagnostic tests to confirm the nonexistence of serial correlation, heteroscedasticity and the normality of residuals. $Breusch-GodfreyLM$ and $Breusch-Pagan-GodfreyHeteroskedacity$ tests confirm that there is no autocorrelation and heteroskedasticity problems in the long- and short-run models. Jarque–Bera test indicates that residuals have normal distribution. Diagnostic tests results confirmed that the coefficient estimates are reliable.

Finally, AESTAR-ECM Granger causality test is employed to investigate whether there is any causal association running from estimators to EF. The causality test results in Table 6 demonstrate that there is unidirectional causal relationship from $GDPPC$ to EF at 1% significance level in the short run. The null hypothesis of non-causality is not rejected from $REMIT$ to EF, from FDI to EF, from $CREDIT$ to EF.

Robustness check

For the robustness checks, we performed Fourier-Shin cointegration test propounded by Tsong et al. (2016). Tsong et al. (2016) developed the Fourier Shin cointegration test by adding the Fourier trigonometric functions to the Shin cointegration test. This method allows for structural changes unknown form, number and time.

Table 6 The Results of Granger Causality Test in Short-run

Null Hypothesis	F statistics	Probability
$\Delta REMIT \rightarrow \Delta EF$	2.634	0.112
$\Delta GDPPC \rightarrow \Delta EF$	46.95***	0.000
$\Delta FDI \rightarrow \Delta EF$	0.959	0.333
$\Delta CREDIT \rightarrow \Delta EF$	0.096	0.757

*** indicates the rejection of null hypothesis of non-causality at the 1% significance level. Δ denotes first difference operator

First, the existence of long run relationship between variables is tested using Fourier-Shin cointegration test. The result of FShin test in Table 7 indicate that the null hypothesis of no cointegration cannot be rejected at 1% significance level. The F-test also show that the fourier terms (sin and cos) are significant at 1 percent significance level. These findings suggest that the FShin fourier cointegration test is appropriate method for our model and there is long run relationship between the variables.

Tsong et al. (2016) fourier cointegration estimates in Table 7 demonstrate that all the variables have significance effects on ecological footprint in India. The coefficients of remittance inflows and economic growth are positive and significant at 1% percent level. Financial development and foreign direct investment are also found to have a significant detrimental impact on the ecological footprint. Comparing coefficient estimates of Tsong et al. (2016) Fourier Cointegration and Hepsag (2021b) asymmetric ESTAR methods, it is observed that remittance inflows, economic growth and financial development yield similar results. However, FDI inflows is found to be statistically insignificant in the asymmetric ESTAR cointegration method, whereas it is statistically significant in the Tsong et al. (2016) Fourier Cointegration.

Conclusion and Policy Implications

Over the past two decades, the drive to improve environmental quality has been on the agenda of most governments, policy makers and researchers around the world. This is mainly because rapid urbanization, industrialization, population growth and energy use have led to environmental degradation. Since the 2000s, India has doubled its per capita income through increased productive capacity and industrialization, but this has come at the cost of a deterioration in the quality of the environment.

Table 7 Tsong et al. (2016) Fourier Cointegration Estimates

Fourier-Shin Cointegration Test		Tsong et al. (2016) Fourier Cointegration		
		Variables	Coefficients	t statistics
Frequency	3	GDPPC	0.822***	28.955
Min SSR	0.00579	REMIT	1.563***	24.488
FShin Test Stat	0.290*	FDI	0.015**	1.854
F test	54.94	CREDIT	0.132**	10.310
		Sin	-0.087***	-7.990
		Cos	-0.042***	-19.624

* implies that the null hypothesis of no-cointegration is rejected at 1% significance level. Critical value for FSHIN cointegration test at 1% significance level (for k = 1 and p = 3) is 0.130. 1% critical value for F test is 5.774. *** and ** represent the significance at the 1% and 5% levels, respectively

Remittances are one of the most important foreign capital sources for developing countries in the process of economic growth. Remittances influence household disposable income, consumption, investment and savings decisions. They also have an impact on industrial production through the creation of new jobs and the expansion of production capacity. All these developments exacerbate the environmental pollution.

This study investigates the linkage between remittance inflows and environmental quality in India from 1975 to 2022. For this purpose, Hepsag (2021b) asymmetric smooth transition models is performed to account for structural breaks and nonlinear structure together. In addition to the methodological contribution to the existing literature, this study uses the ecological footprint as a more comprehensive and broader proxy of environmental quality than carbon dioxide emissions. It is also presented the robusted check of the analysis using the Tsong et al. (2016) fourier cointegration test. Asymmetric ESTAR and Tsong fourier cointegration tests results reveal that remittance inflows and economic growth contribute environmental pollution in the long and short run in India. The coefficients of financial development and FDI inflows are also positive, and thus exacerbate environmental deterioration.

The negative relationship between remittances and the ecological footprint highlights the need for policies to reduce the detrimental impacts of remittances. Despite their negative impact, the stimulating effect of remittances in the economic development process in India cannot be ignored. The channeling of remittances into green energy projects can be an opportunity for India to wean itself off its dependence on fossil fuels. To achieve this, governments can encourage green energy investments while taxing projects that increase fossil fuel use. The government can offer tax rebates on green and energy efficient appliances and electric vehicles to encourage the use of these products. Incentives can be developed for renewables such as solar or biomass. These are less costly and do not require infrastructure. Financial institutions can be encouraged to have more appropriate loans for investments in clean and sustainable energy. Governments can devote more resources to the promotion of technological advances in the industrial sector, such as the provision of loans for low-carbon investments and the financing of renewable energy projects. It is also important to take binding steps to provide technological and financial assistance to help developing countries make the transition to green energy as part of global initiatives to prevent climate change and pollution.

Declarations

Ethics Approval and Consent to Participate Not applicable.

Competing Interests The authors declare no competing interests.

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