Pakistan Journal of Commerce and Social Sciences
2022, Vol. 16 (3), 424-451
Pak J Commer Soc Sci

Remittance Inflows, Technological Innovations, Financial Development and Ecological Footprint: A Global Analysis Using PSQR Approach

Maria Mazhar
School of Economics, Quaid-i-Azam University, Islamabad, Pakistan
Email: mariamazhar28@yahoo.com

Muhammad Tariq Majeed
School of Economics, Quaid-i-Azam University, Islamabad, Pakistan
Email: tariq@qau.edu.pk

Zubia Hussain (Corresponding author)
School of Economics, Quaid-i-Azam University, Islamabad, Pakistan
Email: zubia@eco.qau.edu.pk

Article History

Received: 19 June 2022 Revised: 17 Sept 2022 Accepted: 26 Sept 2022 Published: 30 Sept 2022

Abstract

The present research aims to investigate the influence of remittance inflows on the ecological footprint (EFP). It also seeks to evaluate the interactive effects of technological innovation and financial development on the ecological footprint covering the panel data for 94 countries from 1980 to 2021. Estimation is performed using the software Stata 15 and applying the pooled ordinary least squares (POLS) and panel simultaneous quantile regression (PSQR) techniques. In a worldwide panel, the findings indicate that both remittance inflows and technological innovations reduce EFP. Remittance inflows, in contrast, might degrade environmental quality by encouraging technical advancements and financial development. In addition, the study's finding confirms the environmental Kuznets curve (EKC) theory in most of the quantiles. The overall findings imply that, while remittance inflows are beneficial to environmental quality, they may also degrade it through technical progress and financial development. Therefore, regulating and redirecting remittances toward environmental sustainability will assist governments in meeting their environmental objectives.

Keywords: remittances, technological innovations, patents, financial development, Environmental Kuznets curve, energy consumption, urban population.

1. Introduction

1.1 Background of the Study

Migration of individuals from one location to another in search of better opportunities is a very old option for optimizing well-being. Humans are sometimes compared to birds because of their migratory nature, as Massey et al. (2005) said, "Like many birds, but unlike most other animals, humans are a migratory species." Global migration, however, is expanding at an alarming rate. According to World Migration Report (2022), 281 million migrants are recorded globally in the year 2020 compared to 88 million migrants in 1970. These migrants contribute to the global economy through remittance transfers. Global remittances have recently increased dramatically in comparison to prior years. International remittances increase to 702 billion U.S. $ in 2020 from 128 billion U.S. $ in 2000 (World Migration Report, 2022).

1.2 Remittances Inflows, Technological Innovations, Financial Development and Environmental Quality

These remittance inflows have a remarkable impact on households' income (Prabal & Dilip, 2012), consumption patterns (Lim & Basnet, 2017), investment level (Meyer & Shera, 2017), employment opportunities (Mazhar et al. 2020), and the economy's gross domestic product (GDP) (Guha, 2013). These inflows influence environmental quality either constructively or destructively. On one hand, Remittances improve households' affordability to buy more luxury items such as automobiles and various means of transportation, hence increasing their consumption expenditures, hence burdening the environmental (Ahmad et al., 2022). On the other hand, remittances can reduce environmental degradation by increasing the real exchange rate, stoking inflation, limiting labor market participation, reducing business activities due to labor-leisure trade-off, and lowering individual consumption due to inflationary pressure caused by the widening demand-supply gap (Narayan et al., 2011; Guha, 2013).

The growing significance of remittances has prompted academics to investigate their potential as a possible indicator of environmental quality. Despite the small number of empirical investigations, they offered evidence for remittances' major effect on environmental change. According to Sharma et al. (2019) and Wang et al. (2021), remittances have a positive influence on environmental quality, however, Ahmad et al. (2019), Rahman et al. (2019), Khan et al. (2020), and Yang et al. (2020) have reported a negative impact on environmental quality. Furthermore, the nonlinear and inconclusive outcomes are also revealed by some scholars (Brown et al., 2020; Neog & Yadava, 2020; Qingquan et al., 2020; Usama et al., 2020; Villanthenkodath et al., 2020; Wawrzyniak & Doryń, 2020; Karasoy, 2021; Usman & Jahanger, 2021; Wang et al., 2021; Yang et al., 2022; Ahmad et al., 2022).

Moreover, remittances have a great impact on the environment through two main channels: technical advancement and financial progress. Remittances can be used to supplement formal or informal finance, helping households and businesses overcome liquidity constraints and invest in new technologies and activities (Wouterse, 2010). The adoption and utilization of innovative technology in turn have an influence on environmental quality. On one side, they are beneficial to the ecosystem in the form of green technology (Andersen, 2005), which promotes eco-friendly economic growth (Yang et al., 2021). However, on the other side, in the presence of "rebound effects" technological breakthroughs damage the environmental quality (Majeed, 2018; Sorrell et al., 2009).

Furthermore, remittances may highly affect the planet through financial sector development. It is well explained by Ahmad et al. (2019) through the "five-stage interaction mechanism." According to this mechanism, remittances affect the environmental quality by enhancing aggregate demand due to rising consumption activities followed by huge industrial expansion. Thus, environmental quality suffers as industrial output and financial development expand. Financial development also contributes to environmental pollution by encouraging large corporations to use inefficient production processes to gain higher economic benefits (Jensen, 1996). On the other side, the technique effect generated by financial sector development improves the quality of the environment through green financing (Zhang, 2011; Al-Mulali et al., 2015; Zaidi et al., 2019; Majeed & Mazhar, 2019; Tahir et al., 2021).

1.3 Research Gap and Contribution

The present analysis offers a comprehensive outlook of the relationships among remittance inflows, technical advancements, and ecological footprint. This work aids the existing knowledge and fills gaps in a multitude of ways. Firstly, the bulk of research examining the environmental impact of remittance inflows utilizes CO_2 emissions as an environmental indicator (Sharma et al., 2019; Brown et al., 2020; Neog & Yadava, 2020; Qingquan et al., 2020), Usama et al., 2020), Villanthenkodath et al., 2020; Wawrzyniak & Doryń, 2020; Yang et al., 2020; Karasoy, 2021; Wang et al., 2021; Zafar et al., 2021; Jafri et al., 2022). This only captures one aspect of the ecosystem since it is only one component of the environment. The present study captures many dimensions of the ecosystem by employing EFP as a reliable and comprehensive measure of the environment. Although both Usman & Jahanger (2021) and Yang et al. (2021) employed EFP, Usman & Jahanger (2021) used limited data, whereas Yang et al. (2021) focused on the regional viewpoint. Second, all available studies used data primarily from 1990 to 2016, and none of the studies used updated data and current scenarios in their analyses. The current analysis makes use of a wider panel data set and spans the time period from 1980 to 2021.

Thirdly, this study adds to the global economy literature by investigating contemporary issues on a global level (covering 94 countries), as both the environment and remittances are important worldwide. Internationally, environmental sustainability is a major problem, and migration and financial inflows in the form of remittances have risen as travel facilities have improved and capital mobility has been less restricted. Fourthly, the study provides both direct and indirect environmental impacts of remittances. Only Yang et al. (2021) empirically analyzed this aspect, however, they restricted their analysis to BICS economies. Finally, as it is well accepted that environmental challenges are unparalleled in the global economy, capturing the conditional distribution of the EFP is critical for obtaining robust and efficient estimates. For this purpose, the panel simultaneous quantile regression (PSQR) method is applied.

1.4 Research Questions and Implication

The present study attempts to answer the following three questions: First, do remittance inflows directly influence the ecological footprint in a global economy? Second, whether there exists an indirect effect of remittances on the environment through the channels of technological advancement and financial development or not? Third, whether technological innovations and financial development affect the ecological footprint or not at a different level of ecological footprint? The present research investigation will provide valuable insight to global economic policymakers on how to preserve and divert sustainable use of remittances while keeping the environment, financial development, and technology innovation under consideration.

To explore the mentioned research questions remaining part of the study is organized as follows: Section 2 comprises both a theoretical and empirical literature review. Section 3 contains data, econometric modeling, and methodology. Section 4 reports results and discussions. Section 5 summarizes the current study's primary results, consequences, and policy suggestions.

2. Literature Review

Environmental sustainability is a prerequisite for the survival of all species existing in the universe. Yet the nature of the environment is vulnerable to different factors. The subject matter of the present study is to investigate the relationship between remittances, technical advancements, the financial sector, and ecological footprint. Some scholars and researchers advocate the constructive role of remittances, technological innovations, and the financial sector in affecting environmental sustainability while many scholars believe that these variables harm the environment. The literature section explains the respective issue using theoretical underpinnings followed by empirical studies.

2.1 Remittances Inflow and Environmental Quality

Remittances have a simulative effect on environmental quality. A rise in remittances raises households' income in developing nations (Prabal & Dilip, 2012). As per the permanent income hypothesis, a persistent increase in income raises consumption in the current period (Lim & Basnet, 2017). However, a temporary increase in the level of income leads to a rise in savings (Delpierre & Verheyden, 2014). Thus, remittances lead to an increase in aggregate demand and bank deposits (Graziani, 2003; Sexton, 2015; Irons & Irons, 2019). A rise in aggregate demand boosts production and consumption, while a rise in bank deposits boosts the saving and baking sector's capacity to lend. Finally, an increase in economic activity and the financial sector's development influence environmental quality (Grossman & Krueger, 1995; Holtz-Eakin & Selden, 1995).

To meet rising aggregate demand, production activities (mainly based on conventional energy) expanded involving high-energy usage, additional land area for building and expanding business horizons, and the discharge of pollution emissions. Increasing saving, on the other hand, helps financial sector development by allowing banks to lend more money. The expansion of the financial industry has an impact on the environment, both positively and negatively depending upon the path followed (Meadows, 1972). For example, if the financial sector provides green financing, then it will have a favorable impact on the environment (Tamazian & Rao, 2010; Majeed & Mazhar, 2019). Otherwise, by ignoring these attempts it damages the ecosystem services by expanding unsustainable practices (Tahir et al., 2021; Yang et al., 2021).

Empirical studies are reporting limiting work-relating remittances to environmental quality. Rahman et al. (2019), based on the ARDL (autoregressive distributed lag model) approach, predicted the positive contribution of remittances in CO_2 emissions. Similarly, using the non-linear ARDL model, Ahmad et al. (2019) highlighted the significant and asymmetric role of remittances in affecting CO_2 emissions. Khan et al. (2020) supported the remittances-environment-led hypothesis in BRICS economies. Their results showed a positive impact of remittances on environmental degradation for Brazil, Russia, China, and South Africa, while a negative impact for India.

Furthermore, Sharma et al. (2019), Wang et al. (2021), Wawrzyniak & Dory (2020), and Arogundade et al. (2022) investigated the positive environmental consequences of remittance inflows. Their findings suggest that increased remittances steer households toward environmentally friendly technology such as solar panels for power generation. On the other hand, research such as Ahmad et al. (2019), Rahman et al. (2019), and Khan et al. (2020) revealed that remittances harmed the environment. Rising remittances encourage consumption and saving, leading to increased anthropogenic activity. In addition, some studies concluded the asymmetric and inconclusive relationship among the variables of concern (Brown et al., 2020; Neog & Yadava, 2020; Qingquan et al., 2020; Usama et al., 2020), Villanthenkodath et al., 2020; Yang et al., 2020; Karasoy, 2021; Usman & Jahanger, 2021; Zafar et al., 2021; Jafri et al., 2022; Yang et al., 2021).

2.2 Technological Innovation and Environmental Quality

The theoretical foundation of the link between technologies and environmental sustainability can be explained following the "ecological modernization theory." This theory was developed by university academics in the early 1980s (Huber et al., 1980s). It suggests that the transition of nations from the low stage to the middle stage of development level increases environmental pollution, as the nation prioritizes growth expansion during this transition. While the transition to the advanced stage results in a priority diversion towards eco-friendly technological innovations. Thus, the second stage results in good quality environment (Andersen, 2005; Majeed & Mazhar, 2019). On the other side, if innovations are purely growth-driven, then economic expansion results in poor environmental quality due to massive energy consumption.

Another concept linking technological advancement to environmental sustainability is "rebound effects" (Lin & Liu, 2012; Majeed, 2018). When technical advances emerge, they take one of two pathways, according to this terminology. Initially, technology improves energy-efficient manufacturing systems, and then it boosts economic growth. The growth expansion enhances energy demand in an economy, partially or offsetting the energy saved by energy-efficient manufacturing techniques. Economic expansion may increase energy consumption, resulting in increased pollutant emissions, which will create environmental degradation.

Empirical studies utilizing various techniques, time horizons, sample selections, and model specifications revealed that technological developments have a mixed environmental impact. Most academics believe that technical developments have a role in enhancing environmental quality. For instance, Gerlagh (2007), Ahmed et al. (2016), Li et al. (2017), Churchill et al. (2019), and Mongo et al. (2021) suggested the supportive role of technological innovations in mitigating CO2 emissions. Meanwhile, many scholars also believe in the destructive role of technological innovation in environmental quality (Shaari et al., 2016; Santra, 2017; Cheng et al. 2019; Rout et al., 2022).

2.3 Financial Development and Environmental Quality

Financial development is associated with environmental quality through the direct, business, and wealth effects (Sadorsky, 2011). These effects stimulate energy consumption, which in turn contributes to greenhouse gas emissions. Similarly, financial development influences energy demand through two other effects known as “the scale and the technique effects” (Meadows, 1972). When economic activities, led by financial development, follow the scale effect, production based on fossil-fuel energy increases which negatively influences the environment. When the technique effect occurs, production becomes more energy efficient and environmentally benign. Besides, financial growth can lead to the route of clean energy use in the form of eco-conscious appliances (i.e., cooking gadgets, electric composters, dishwashers, and washing machines) and eco-friendly instruments (i.e., green bonds and green insurance).

The empirical findings suggested an inconclusive association between financial development and environmental quality. Some studies have found that financial development has a favorable impact on environmental quality (Tamazian & Rao, 2010; Tang & Tan, 2015; Charfeddine & Kahia, 2019; Majeed & Mazhar, 2019; Zaidi et al., 2019). These studies support the idea that financial growth directs funds to environmentally beneficial initiatives. On the contrary, various studies reported adverse effects of financial development on environmental quality (Zhang, 2011; Al-Mulali et al., 2015; Bekhet et al., 2017; Cetin et al., 2018; Tahir et al., 2021).

2.4 Remittance Inflows, Technological Innovations, Financial Development and Environmental Quality

Remittances have a significant impact on environmental quality, either positively or negatively, through three key channels, as previously noted. Firstly, it directly affects income which by following the path described by the "five-stage interaction mechanism" (Ahmad et al., 2019) either positively or negatively determines environmental sustainability. Moreover, remittances indirectly narrate the environmental quality by affecting financial sector development and technological innovations. Remittances by bringing the development in the financial sector have both positive and negative effects on resources' utilization. Promoting green projects and eco-appliances can benefit the environment.

Otherwise, ignoring the environment and facilitating everyone to use eco-friendly or unfriendly investments and technology can degrade the environment. Thirdly, as remittances are a source of finance in many economies, a portion of remittances is invested in new technology (Wouterse, 2010). In this aspect, remittances have an indirect impact on the environment due to technological advancements. The effects are both positive and negative, as remittances bring technological innovations into an economy, which improves energy efficient-driven production mechanisms, thus improving environmental quality, or deteriorating the environment by encouraging the increased use of technology that requires power from traditional unsustainable sources.

Thus, it is critical to investigate the impact of remittances on the environment using technical breakthroughs and financial development in the analysis. In this context, Yang et al. (2021) conducted research on BICS economies using data from 1990 to 2016. Their study concludes various conclusions by calculating the long-term elasticities. Their findings support the positive relationship among remittance (individual impact), financial development (individual impact), and ecological footprint. On the other hand, technological innovation and remittances' interactive impact with technological innovations and financial development appeared with a negative sign signifying their favorable impact on environmental quality.

2.5 Summary, Gaps, and Contribution to the Literature

The conclusion drawn from the existing theoretical and empirical research is that remittances, technological improvements, and financial development are important factors in changing the status of the environment. Remittances along with technological innovations and financial development affect the environment both positively and negatively. According to the literature assessment, empirical research on remittances and the environment has just recently started thus pointing to various shortcomings. For instance, studies by Ahmad et al., (2019), Sharma et al. (2019), Brown et al. (2020), Neog & Yadava (2020), Qingquan et al. (2020), Usama et al. 2020, Villanthenkodath & Mahalik (2020), Wawrzyniak & Doryń (2020), Yang et al. (2020), Wang et al., (2021), and Jafri et al., (2022) utilized carbon dioxide emissions in metric tons as a measure of environmental quality. Because these studies are unable to capture the broad dimensions of the ecosystem services, the use of just one restricted proxy variable may skew the results of previous investigations.

Furthermore, many of these studies employed time series or regional data and provided county or region-specific results. They also used conventional panel data approaches including pooled OLS, fixed effects, random effects, and GMM, and solely looked at the direct influence of remittances on carbon emissions. Usman & Jahanger (2021) proceed and incorporate EFP data into their research, yet their analysis is confined to limited data. Yang et al. (2021) expanded the literature by using the EFP as a measure of the environment and investigating both direct and indirect environmental effects. Their research, however, is limited to the BICS economies, and their findings are more applicable to these four nations.

Based on the aforementioned domains of the literature, the current study contributes to the literature in a variety of ways. To begin, this study uses the EFP as a reliable and holistic assessment of the environment to acquire more accurate and reliable insights. EFP is regarded as reliable since it keeps track of data on ecological deficits and surpluses and offers an efficient gauge of decreasing natural resource reproduction by collecting data on water and land (crop and pasture) as well as other resources (Aydin et al. 2019). Furthermore, the analysis extends the time span from 1980 to 2021, making use of maximum accessible data. The study is also undertaken for the global economy since all the focused variables are internationally important. Lastly, based on EFP's unparalleled nature across the economies the SPQR method is employed to provide efficient estimates in capturing the distributional condition of EFP.

3. Data, Model, and Methodology

The present study aims to explore the direct and indirect impacts of remittance inflows on ecological footprint. The data of the dependent variable EFP is collected from Global Footprint Network (2022), the data on total patent applications is gathered from the World Intellectual Property Organization (2022), and data for all the remaining variables are taken from World Bank (2022). As previously discussed, the financial system and technological advancement play a larger role in influencing not just economic development but also environmental quality. Remittance inflows have an impact on the financial system and technological progress by serving as an additional financial source. This suggests that remittance inflows, in addition to their direct influence, have an indirect effect on environmental quality through financial development and technical improvement. Therefore, based on earlier literature, notably the work of Yang et al. (2021) the research's econometric models are structured as follows:

$$\mathrm{LEFP_{it}} = \beta_0 + \beta_1\mathrm{GDPC_{it}} + \beta_2\mathrm{GDPC^2_{it}} + \beta_3\mathrm{LPR_{it}} + \beta_4\mathrm{LTI_{it}} + \beta_5\mathrm{LDCP_{it}} + \beta_6\mathrm{LEU_{it}} + \beta_7\mathrm{LUP_{it}} + \varepsilon_{it} \quad (1)$$

$$\mathrm{LEFP_{it}} = \beta_0 + \beta_1\mathrm{GDPC_{it}} + \beta_2\mathrm{GDPC^2_{it}} + \beta_3\mathrm{LPR_{it}} + \beta_4\mathrm{LTI_{it}} + \beta_5\mathrm{LPR} * \mathrm{LTI_{it}} + \beta_6\mathrm{LDCP} + \beta_7\mathrm{LEU_{it}} + \beta_8\mathrm{LUP_{it}} + \varepsilon_{it} \quad (2)$$

$$\mathrm{LEFP_{it}} = \beta_0 + \beta_1\mathrm{GDPC_{it}} + \beta_2\mathrm{GDPC^2_{it}} + \beta_3\mathrm{LPR_{it}} + \beta_4\mathrm{LTI_{it}} + \beta_5\mathrm{LDCP_{it}} + \beta_6\mathrm{LPR} * \mathrm{LDCP_{it}} + +\beta_7\mathrm{LEU_{it}} + \beta_8\mathrm{LUP_{it}} + \varepsilon_{it} \quad (3)$$

Where EFP is the ecological footprint measured in global hector per person. It is considered a comprehensive and reliable environmental indicator. It contains many dimensions of the environment such as area used for building, harvesting, and grazing, carbon footprint, fishing grounds, and forest products. It is simple to learn, deals with a variety of data on natural resources, and provides information on ecological deficit/surplus and the gap between natural resource demand and the renewal of natural resources (Senbel et al., 2003; Katircioglu et al., 2018; Majeed & Mazhar, 2019). PR is the remittance inflows measured in terms of as a percentage of GDP. According to World Bank (2022), the flow of individual transfers and salaries of employees from a foreign country to a local country is called remittance inflows.

TI is the technological innovations proxied through total patent applications (direct and PCT national phase entries). According to World Intellectual Property Organization (2022), a patent is a right of innovation in the form of technology, idea, or anything that has the technical ability to solve a problem. An innovator is eligible to hold this right after revealing the technical knowledge regarding his/her innovation. GDPC is the per capita gross domestic product measured in terms of 2015 US $. It comprises gross value added by all resident producers in the economy including any product taxes and subtracting any subsidies. $GDPC^2$ is the square of per capita gross domestic product. DCP is domestic credit to the private sector measured as a percentage of GDP. It includes financial resources provided to the private sector by financial intuitions.

EU is the energy consumption taken in terms of kg of oil equivalent per capita. It refers to the primary EU before any transformation in the form of other e-use fuels. It equates local production, imports, and changes in stock minus exports and fuels provided to ships and aircraft involved in international transportation. UP is the urban population measured in terms of the percentage of the total population residing in urban areas. (World Bank, 2022). PR*TI is the interaction term of PR, and TI and PR*DCP is the interaction term of PR and DCP. L represents the variable transformation in the logarithm. ε is the error term, β_0 is the intercept, and the remaining $\beta_{1,..8}$ are slope coefficients. *i* in subscript shows the number of cross-sections (N = 94, see table A for the detail) and *t* shows the time period from 1980 to 2021.

The pooled ordinary least squares regression (POLS) (for the baseline estimation) and panel simultaneous quantile regression (PSQR) is used for the analysis. SQR is a robust regression approach that tackles the error term non-normality and heteroscedasticity. Simultaneous quantile regression can show if independent variables have non-constant or variable effects over the whole distribution of the dependent variable (Koenker & Hallock, 2001). The general τth quantile of the conditional distribution specification of the LEFP (dependent variable) is expressed in the following manner:

$$Q_t\left(\frac{LEFP_{it}}{X_{it}}\right) = \vartheta_\tau + \delta_\tau X_{it} + \vartheta_\tau \varepsilon_{it} \quad (4)$$

$$(Q_t(\vartheta_\tau) = \min_{\vartheta} \sum_{i=1}^{n} [\left|\ln EFP_{i,t} - \vartheta_\tau X_{it}\right|]) \quad (5)$$

Where LEFP is the outcome variable and X is the vector of independent variables in both equations. The parameters are obtained by minimizing the absolute values of residual and are shown in equation 5.

4. Results and Discussion

4.1 Results of Statistical Analysis

4.1.1 Summary Statistics

The summary statistics for the entire variable included in the regression are reported in table 1. Here, on average, the EFP is 3.160 GHA per person while it is the maximum for the Bahamas, in 1980 (23.9463) and remain minimum of about 0.4599 for the economy of Bangladesh during 1994. Remittance inflows remain highest in Lesotho in 1987 and minimum in Afghanistan from 2005 to 2007. TI is maximum in China in the year 2018 and minimum in Cuba in 1992, 1993, Cyprus in 1980, and many other nations. The financial development was highest in Iceland during 2006 and minimum in Guinea-Bissau in 2002 and many other countries.

Table 1: Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
EFP	4,958	3.1609	2.594834	0.4599	23.9463
PR	6,080	4.1924	10.73682	0	235.924
TI	4,079	14715.0	77629.01	1	1460243
DCP	5,414	43.6695	40.71043	0	304.575
GDPC	7,684	12986.7	19936.44	167.245	181709.3
EU	4,781	2393.88	2939.556	9.54806	28902.8
UP	9,020	55.5897	24.86784	4.339	100.00

4.1.2 Correlation Matrix

Table 2 reports the correlational relationship between the dependent and independent variables. The correlation between PR, TI, and DCP is moderate, and a positive relation is suggested between EFP and TI, and DCP while a negative relationship is observed between PR and EFP. The correlation among GDPC, EU, UP, and EFP is high and positive.

Table 2: Correlation Matrix

	EFP	PR	TI	DCP	GDPC	EU	UP
EFP	1.0000						
PR	-0.3570	1.00					
TI	0.2470	-0.1619	1.00				
DCP	0.5714	-0.2767	0.5093	1.00			
GDPC	0.8425	-0.3117	0.2425	0.6395	1.00		
EU	0.9168	-0.3427	0.2934	0.5476	0.7944	1.00	
UP	0.6943	-0.2978	0.1970	0.4639	0.6028	0.6326	1.00

4.2 Results of Regression Analysis (Pooled OLS and PSQR)

4.2.1 Results of Model 1 (POLS and PSQR)

Table 3 displays the POLS and PSQR results for model (1), respectively. According to POLS findings, per capita income, and its square term did not show any apparent pattern due to the varying levels of EFP in the countries. In this scenario, OLS ignores the environmental condition in the various nations and provides biased outcomes. According to PSQR estimations, in the initial quantile, GDP per capita raises EFP significantly but does not result in a significant fall in EFP even after reaching a certain threshold level. This is because countries with exceptionally low environmental footprints prioritize growth over the environment. Then, as countries' development and carbon footprints grow, the emphasis shifts to environmental conservation. Certain measures are taken to enhance environmental quality by lowering the footprint level, as can be seen by the negative and significant coefficient signs of GDP per capita square from 25^{th} to 75^{th} quantiles. In these quantiles, we observe an inverted U-shaped relationship between GDP per capita and EFP. The last quantile (95^{th}) shows that after reaching a peak of environmental issues, this relationship turned out to be U-shaped. Where the insignificant coefficient of GDP per capita indicates that in countries with extremely high levels of EFP, GDP per capita alone is insufficient to improve environmental quality, rather it worsens it (as shown by the significant coefficient of per capita income square). The findings agree with those of Tenaw & Beyene (2021) and contradict Pata & Caglar (2021).

Regarding the impact of remittance inflows on both POLS and PSQR, analyses demonstrate that a 1% increase in remittances inflows leads to a 0.015 % (POLS) and a 0.026 % (5^{th} quantile) to a 0.017 % (95^{th} quantile) reduction in EFP. Remittances may help to build human capital through funding health and education, as well as raise environmental awareness and move human behavior toward environmental sustainability. The remittance inflows contribute to economic growth and development and can eventually be utilized to supplement financial resources for productive enterprises. The remittances can be utilized to fund green technologies, alternative energy initiatives, or environmentally beneficial industrial processes that minimize EFP. However, as we move up the quantiles, the coefficient size decreases, becoming less significant and finally insignificant, showing that in nations with greater levels of current EFP, remittances are insufficient to meet environmental issues. The influence of other factors such as internal migrants' remittances and remitters, as well as their family structure (number of family members, dependent members, age of family members, and so on), are relevant in this perspective. The presence of large domestic migrant remittances in comparison to fewer foreign migrant remittances will make their impact less significant. Furthermore, the remitters and their family structure are important; for example, if the remitters' family migrates with them, lowering the family size in the origin nation, the remittance income of that family may not have a substantial influence on that country's ecological footprint. These findings are in line with Arogundade et al. (2022) and contrast with Jamil et al. (2022).

Technological advancements have a tremendous influence on environmental quality since they may either improve or degrade it. The TI coefficient is negative and statistically significant at the 1% level of significance, suggesting that its impact is comparable in most quantiles. At the 5% level of significance, the coefficient of TI in the first quantile is positive and statistically significant, meaning that a 1% increase in TI boosts EFP by 0.017%. This is because environmental standards are not valued in nations with low levels of EFP, and with new technology, individuals opt to go for it, buying new appliances without considering the environmental implications, which raises EFP. However, as countries begin to experience environmental challenges, a focus on environmental standards and green technology will aid in the reduction of EFP (as shown by the negative coefficient significant signs in upper quantiles). This finding supports the ecological modernization theory, which claims that technical and eco-innovations, as well as environmental regulations, may address environmental concerns. Green growth, carbon fees, and incentives for environmentally friendly technology also help to regulate EFP in the sample economies. Jiang et al. (2022) find comparable results, but Mo (2022) concludes that firms will not benefit the environment unless and until they join carbon trading programs. Yang et al. (2021) also found similar results.

The role of financial development varies across quantiles. In the initial quantiles, the coefficient has a positive sign and is statistically significant, meaning that a 1% rise in financial development relates to a 0.041% (25^{th} quantile), and a 0.022% (50^{th} quantile) increase in EFP. This suggests that in nations with low levels of EFP, financial development degrades quality. Financial growth promotes environmental harm by rewarding and facilitating financing for the purchase of mechanical machinery, electrical devices, automobiles, and homes. These facilities let investors expand their company scopes and construct new machinery and factories, hence increasing the EFP. These findings are similar to those obtained by Tahir et al. (2021) and dissimilar to those obtained by Paramati et al. (2021). Conversely, in the top quantiles, countries with strong EFP financial development improve the environment insignificantly because huge environmental challenges necessitate a larger push from financial and other regulatory authorities to preserve the ecology.

The energy usage coefficient has a positive sign and is highly significant at a 1% level of significance. A 1% increase in the EU corresponds to 0.464% (POLS), 0.409% (5^{th}), to 0.445% (95^{th}) rises in the EFP. In this aspect, the EU has a greater effect on EFP in countries with higher EFP levels than in those with lower EFP levels. Energy is essential for economic growth and is mostly supplied from conventional sources. Increased energy usage in the form of oil, gas, and coal puts additional strain on the environment by increasing the carbon footprint, exploitation of built-up and other forms of land, and overall ecological footprint (Mehmood, 2022). Nations with higher levels of EFP show that environmental restrictions are not being managed and effectively enforced; EFP is rising in these economies, and the EU's impact is bigger because they rely on conventional energy.

The impact of UP is dominantly positive and significant across all quantiles. This finding favors the argument of Sahoo & Sethi (2022) that urbanization adds to resource degradation by increasing the demand for energy use and resources. According to current research, the impact of UP is greater in countries with low EFP than in those with high EFP. This is because major rural-urban migration has already happened in countries with higher EFP, therefore any increase in UP will have less impact on these nations than on those that are now experiencing massive movement. The findings, in general, are contradictory to Ansari et al. (2022) and invalidate the compact city hypothesis, which holds that urbanization enhances environmental quality by improving resource productivity, economies of scale, and public infrastructure.

Table 3: Results for Model 1 (POLS and PSQR)

Dependent Variable: LEFP (1980-2021)						
	POLS	**PSQR**				
		0.05	**0.25**	**0.50**	**0.75**	**0.95**
LGDPC	0.0517	0.195^{**}	0.343^{***}	0.319^{***}	0.187^{**}	-0.473
	(0.063)	(0.090)	(0.0612)	(0.041)	(0.0812)	(0.398)
LGDPC²	0.0060^{*}	-0.0026	-0.0108^{***}	-0.0091^{***}	-0.0015	0.0365^{**}
	(0.0033)	(0.0042)	(0.0033)	(0.0022)	(0.0042)	(0.0182)
LPR	-0.0151^{***}	-0.0264^{***}	-0.0191^{***}	-0.0126^{***}	-0.0164^{**}	-0.0169
	(0.0041)	(0.0073)	(0.0045)	(0.0038)	(0.0067)	(0.0155)
LTI	-0.0111^{***}	0.0167^{**}	-0.0059	-0.0225^{***}	-0.0217^{***}	-0.0424^{***}
	(0.0034)	(0.0071)	(0.0037)	(0.0045)	(0.0079)	(0.0143)
LDCP	-0.0039	0.0155	0.0408^{***}	0.0223^{**}	-0.00007	-0.0441
	(0.0096)	(0.0222)	(0.0099)	(0.010)	(0.0140)	(0.0322)
LEU	0.464^{***}	0.409^{***}	0.458^{***}	0.515^{***}	0.487^{***}	0.445^{***}
	(0.015)	(0.038)	(0.017)	(0.015)	(0.019)	(0.062)
LUP	0.164^{***}	0.235^{***}	0.0988^{***}	0.0894^{***}	0.163^{***}	-0.0025
	(0.025)	(0.082)	(0.023)	(0.017)	(0.028)	(0.193)
CONSTANT	-3.864^{***}	-4.882^{***}	-5.100^{***}	-5.105^{***}	-4.456^{***}	-0.119
	(0.235)	(0.303)	(0.213)	(0.156)	(0.313)	(1.597)

Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

4.2.2 Results of Model 2 (POLS and PSQR)

The estimation result for the second model is reported in table 4. This estimation is performed by incorporating the interactive effect of personal remittance and technological innovations in the model. The POLS findings are likewise negligible in this case, indicating a biased outcome. The PSQR estimates presented to demonstrate that the EKC theory is validated even at the extremely low quantile (0.05), showing that in countries where remittance transfers help to lessen environmental pressures, there is an inverted-U-shaped relationship between income per capita and EFP. The scale effect prevails in all quantiles. However, in economies with a larger extent of EFP, this link may be less hopeful because merely remittances are unable to drive technological innovation when domestic factors dominate. Tenaw & Beyene (2021) discovered comparable findings.

Furthermore, remittance inflows continue to play an environmental sustainability role, with a 1% increase related with a 0.049%, 0.087%, 0.051%, 0.025%, -0.015%, and 0.004% drop in EFP. The significant impact in the initial quantiles shows that using remittance payments to improve human capital would encourage human behavior toward environmental sustainability. Remittance-based income can also be utilized for green finance and green instrument launch which improve environmental quality. Unfortunately, in nations with more severe resource degradation, remittances alone are insufficient to address the issue. Yang et al. (2021) and Karasoy (2021) reached similar conclusions while Khan et al. (2020) found an unsustainable impact of remittances. Similarly, new technologies increase environmental quality. The impact is particularly strong in countries with higher EFP. The findings confirm the ecological modernization concept as well as Yang's (2021) conclusion that ecologically oriented technological initiatives, green growth, and contemporary finance tools help countries to manage their rising EFP levels.

The indirect impact of personal remittance is incredibly negative for the environment, as PR may increase EPF by stimulating technological innovation. An increase in remittance-based personal income boosts aggregate consumer spending and industrial production. As consumer spending increases, manufacturers seek to create new industrial units to meet domestic demand. Furthermore, remittance-based income is utilized for research and development, and human and physical capital to boost technological innovations. Such expenditures to support technological innovations also include expenditure on transportation and travel, industrial setup, energy consumption, research centers, and imported technology which might increase EFP. That is, the investment and energy consumption associated with the process of technological innovation may result in higher EFP. Additionally, many of the technologies we use daily consume far more resources and electricity than they should, and their use and manufacturing can be detrimental. Coal, for example, is used to create energy for the usage of technology. Because of technological improvements, even renewable resources such as trees and water are becoming contaminated or depleted quicker than they can be replenished. These findings are following Ahmad et al. (2019), Rahman et al. (2019), and Yang et al. (2021).

In the beginning quantiles, the impact of financial development is positive and considerable, indicating environmental degradation in nations with low levels of EFP. According to Majeed & Hussain (2022), financial expansion boosts economic activity in countries, increasing demand for and use of conventional energy. Existing and new enterprises use polluted technology to gain economic advantage, and as a result, EFP expands. In the top quantile, the effect is negative and insignificant, implying that financial development can play a sustainable function if adopted as a tool to save resources.

Financial growth promotes environmental harm by rewarding and facilitating financing for the purchase of mechanical machinery, electrical devices, automobiles, and homes. These facilities let investors expand their company scopes and construct new machinery and factories, hence increasing the EFP. These findings are similar to those obtained by Tahir et al. (2021) and dissimilar to those obtained by Paramati et al. (2021). Conversely, in the top quantiles, countries with strong EFP financial development improve the environment insignificantly because huge environmental challenges necessitate a larger push from financial and other regulatory authorities to preserve the ecology. The coefficient of EU is positive and highly significant across all quantiles, inferring that as energy is used in almost every economic activity and is largely generated from traditional sources, degrading natural resources regardless of the degree of EFP in the economy. Liu et al. (2022) found similar results. Finally, the positive sign of UP indicates that the urban population is expanding, imposing additional pressure on EFP by increasing natural resource demand consumption and exploitation. Cui et al. (2022) obtained similar results that contradict Gupta et al (2022).

Table 4: Results for Model 2 (POLS and PSQR)

Dependent Variable: LEFP (1980-2021)						
	POLS	**PSQR**				
		0.05	**0.25**	**0.50**	**0.75**	**0.95**
LGDPC	0.0653	0.376***	0.373***	0.308***	0.190*	-0.438
	(0.063)	(0.053)	(0.059)	(0.0647)	(0.097)	(0.372)
LGDPC²	0.00542	-0.0123***	-0.0125***	-0.0085**	-0.0016	0.0352**
	(0.003)	(0.002)	(0.003)	(0.0035)	(0.0058)	(0.0171)
LPR	-0.0492***	-0.0873***	-0.0514***	-0.0249**	-0.0154	-0.0043
	(0.0082)	(0.010)	(0.0110)	(0.0118)	(0.0140)	(0.0492)
LTI	-0.0072**	0.0209***	0.0007	-0.0188***	-0.0219***	-0.0505***
	(0.0035)	(0.002)	(0.006)	(0.0072)	(0.0068)	(0.0110)
LPR*LTI	0.0053***	0.0082***	0.0050***	0.0020	-0.0002	-0.0021
	(0.0011)	(0.0009)	(0.001)	(0.0014)	(0.0016)	(0.0044)
LDCP	0.0027	0.0304*	0.0472***	0.0296**	-0.0017	-0.0494
	(0.009)	(0.016)	(0.012)	(0.0130)	(0.0094)	(0.0307)
LEU	0.459***	0.391***	0.446***	0.508***	0.488***	0.437***
	(0.0150)	(0.022)	(0.019)	(0.0135)	(0.015)	(0.064)
LUP	0.158***	0.212***	0.112***	0.0901***	0.161***	0.0071
	(0.025)	(0.049)	(0.025)	(0.016)	(0.024)	(0.156)
CONSTANT	-3.902***	-5.543***	-5.254***	-5.061***	-4.457***	-0.233
	(0.233)	(0.239)	(0.200)	(0.225)	(0.376)	(1.550)

Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

4.2.3 Results of Model 3 (POLS and PSQR)

The regression results for our third model are presented in table 5. This model is regressed by incorporating the interaction term of remittance inflows and financial development in the model. In line with the prior two models, the EKC hypothesis is validated here with a larger scale effect. According to the findings, EFP expands initially with an emphasis on development and then declines after reaching a certain level when environmental protection knowledge and technical advances in alternative energy sources improve. This relationship is strongest in the medium quantiles, showing that in nations where remittances stimulate financial development and green finance, the impact of income per capita is beneficial. However, in nations where EFP is more prevalent, this relationship may be less promising because remittances alone are inadequate to generate green financing when domestic factors are dominant. The results are in agreement with Ali et al. (2021) and in contrast with Ullah et al (2021).

Remittance inflows are continuing to exhibit a healthy sign for the environment, with a 1% increase in PR related to a 0.0591% (POLS) to 0.0273% (75th quantile) drop in EFP. According to Karasoy (2021), remittance inflows serve to mitigate EFP levels by encouraging individuals to practice environmental conservation by broadening their ideas via greater health and education. Additionally, the cash can be utilized to fund green projects that assist to preserve environmental quality. Similarly, to the previous model, the impact of PR is negligible at the upper quantile, indicating an ineffectual influence on countries with higher levels of EFP. This outcome contrasts with Jamil et al. (2022), who stated that remittances hurt the environment by increasing carbon emissions in G-20 countries.

The coefficients of technological innovations remain negative and highly significant across all specifications. Innovations play a more ecologically sustainable function in nations with a high level of existing EFP than in those with a low level of EFP. This is because, in countries with higher levels of EFP, a small technological advancement will aid countries in managing their EFP and encourage them to use it more, thereby reducing environmental stress over time. According to Yang et al. (2021), technology advancements, notably in household appliances, will aid in EFP control through energy efficiency.

The indirect impact of remittances is not sustainable, and it has the potential to affect the environment as the financial sector develops. The statistics show that a 1% increase in PR leads to a 0.032% and 0.019% increase in LEFP through financial development in the initial quantiles. This is because an increase in remittances boosts both expenditure and household savings. When a household's savings increase, they prefer to deposit the excess funds with financial institutions. Financial institutions used these deposits to produce credit and profit by charging interest. Industrialists borrow from financial institutions to develop their businesses and build new plants, resulting in increased pollutant emissions and a higher footprint level. These findings are supported by Yang et al. (2020a) and contradictory to Arogundade et al. (2022). In the upper quantiles, however, this impact does not affect LEFP. This might be attributed to various causes such as larger inflows of other capital inflows into the countries, as well as family size and spending and saving patterns of a receipt household.

Unlike the previous models, the overall impact of financial development remains negative across all quantiles. It becomes negative and significant in the final quantile, signifying that more financial growth would lower the ecological footprint in economies with a higher level of EFP since nations with more environmental challenges focus on environmental regulations. These findings agree with those of Majeed et al. (2020). Finally, the EU and

UP have a positive and considerable influence on EFP across all quantiles, resulting in a degradation of environmental quality. These findings corroborate our earlier findings.

Table 5: Results for Model 3 (POLS and PSQR)

Dependent Variable: LEFP (1980-2021)						
	POLS	**PSQR**				
		0.05	**0.25**	**0.50**	**0.75**	**0.95**
LGDPC	0.0546	0.267^{***}	0.384^{***}	0.321^{***}	0.201^{**}	-0.341
	(0.0637)	(0.103)	(0.066)	(0.058)	(0.088)	(0.415)
LGDPC²	0.0061^{*}	-0.0066	-0.0131^{***}	-0.0089^{**}	-0.0023	0.0308
	(0.003)	(0.0054)	(0.003)	(0.003)	(0.0052)	(0.0190)
LPR	-0.0591^{***}	-0.144^{***}	-0.0900^{***}	-0.0389^{**}	-0.0237	0.107
	(0.0163)	(0.026)	(0.027)	(0.017)	(0.0349)	(0.083)
LTI	-0.0091^{***}	0.0185^{***}	-0.0009	-0.0207^{***}	-0.0222^{***}	-0.0500^{***}
	(0.0035)	(0.003)	(0.004)	(0.005)	(0.0061)	(0.0139)
LPR*LDCP	0.0117^{***}	0.0320^{***}	0.0185^{***}	0.0068	0.0015	-0.0297
	(0.004)	(0.006)	(0.007)	(0.004)	(0.0085)	(0.019)
LDCP	0.0026	0.0552^{***}	0.0644^{***}	0.0270^{*}	0.0014	-0.0795^{***}
	(0.009)	(0.014)	(0.015)	(0.014)	(0.016)	(0.021)
LEU	0.456^{***}	0.403^{***}	0.444^{***}	0.507^{***}	0.488^{***}	0.417^{***}
	(0.015)	(0.029)	(0.018)	(0.012)	(0.020)	(0.052)
LUP	0.156^{***}	0.201^{***}	0.0829^{***}	0.0832^{***}	0.159^{***}	0.0165
	(0.025)	(0.040)	(0.025)	(0.013)	(0.023)	(0.190)
Constant	-3.839^{***}	-5.154^{***}	-5.239^{***}	-5.089^{***}	-4.507^{***}	-0.526
	(0.235)	(0.405)	(0.242)	(0.259)	(0.385)	(1.447)

Standard errors in parentheses (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

4.2.4 Ecological Footprint Plot by Quantile

The quantile plot for the outcome variable (EFP) is shown in figure 1. The quantiles are plotted on the x-axis, while EFP's values are plotted on Y-axis. The line shows an abrupt increasing, then flatter, and then again, an increasing trend across the quantiles. This denotes the pace at which EFP increases from quicker to moderate, then back to faster. This is supported by the prior models' findings.

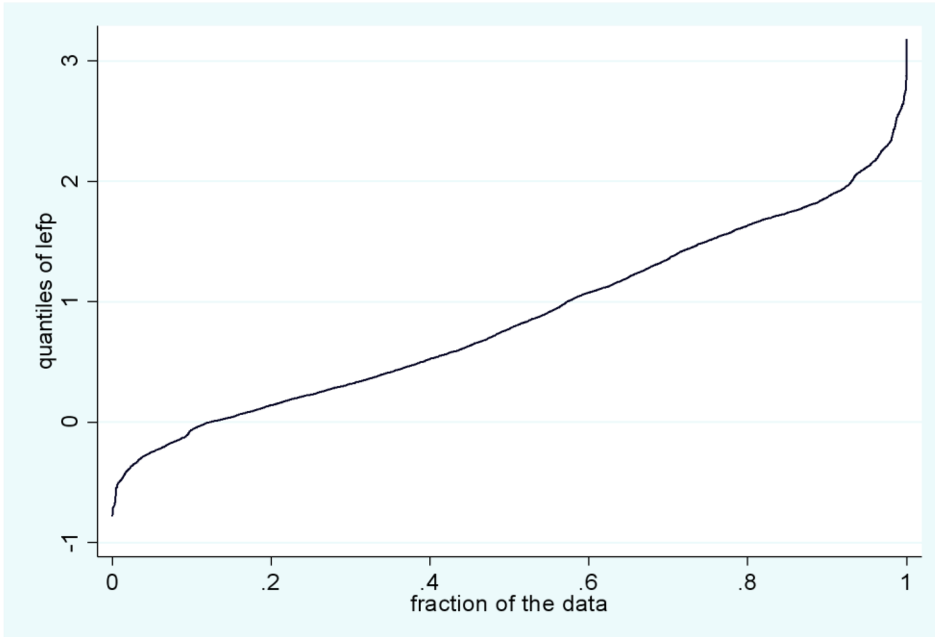

Figure 1: Ecological Footprint Plot by Quantile

4.2.5 Regressors Plot by Quantile

The regressors are also plotted in terms of their quantiles and the results are illustrated in figure 2. The long-dashed line depicts the coefficients of OLS estimates. The confidence interval is represented by the little dotted lines. The OLS estimates are steady, as indicated by the CI. The PSQR approach coefficients are represented by the grey-shaded region. They diverge beyond the dotted lines and show the discrepancy between the POLS method and the PSQR approach, indicating the bias of OLS findings. These findings are supported by the statistics presented in Tables 3 to 5.

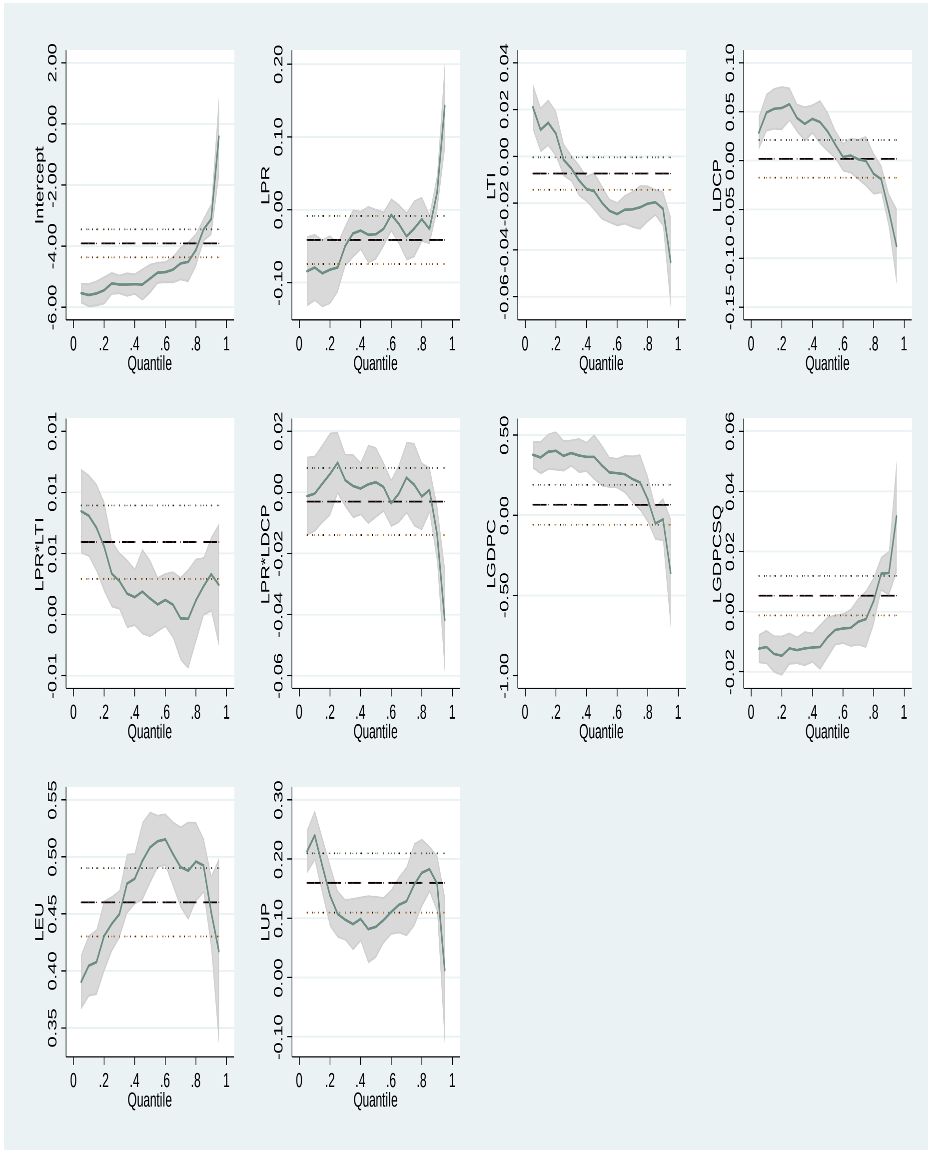

Figure 2: Regressors Plot by Quantile

5. Conclusion

Moving abroad is becoming increasingly popular in the present age when the world has turned into a global village. People moved to foreign countries in search of better education, health care, and employment opportunities, and they sent their earnings back home in the form of remittances. The remittance inflows have an impact on personal and national income, consumption, and production levels, as well as investment and job opportunities. The current study aims to investigate its direct and indirect effects on the ecological footprint in 94 countries. The indirect impact is checked by incorporating the interactive terms of remittance inflows with technological innovations and financial development. For this purpose, the study exploited the data from 1980 to 2021 and applied POLS and PSQR models to estimate the empirical results.

The study's findings are noteworthy. The findings validate the presence of EKC in the sampled nations, inferring that countries with low levels of EFP emphasize growth over the environment, and after suffering environmental pressure, the environment is prioritized over economic growth, but in times of crisis, development alone is ineffective. These findings are consistent with Tenaw & Beyene (2021) and contradict form Pata & Caglar (2021). The impact of remittances stays favorable, and it diminishes along higher quantiles, implying that in more serious environmental challenges, only remittances cannot address the problem even though they mitigate it. Arogundade et al. (2022) support these findings, which disagree with Jamil et al (2022). The indirect effect reveals that remittances damage the environment through financial development and technological advancements in countries with lower levels of EFP, but have no significant impact in other countries. These findings are consistent with those of Yang et al. (2021) and Yang et al (2020a). Aside from that, individual financial development, energy use, and urbanization appear to be degrading ecological services.

5.1 Theoretical Implications

This study provides theoretical and practical implications based on its findings. In theory, (i) the findings favor the "productive use" of remittance inflows in lowering the EFP. (ii) the findings highlight the "careless approach" of economic institutions (financial sector, technology, and R&D firms) to boost EFP through PR. (iii) the results favor the ecological modernization theory (as indicated by the negative sign of the TI coefficient), (iv) the EKC theory is confirmed, and (v) the compact city theory is rejected. All of this contributes to a better understanding of how and to what extent these concepts are important for the maintenance of environmental stress. Based on this theoretical support, steps can be taken with proper knowledge while keeping the expected response and strategies on notice.

5.2 Practical Implications

This research also offers some practical implications. First, because the direct relationship between PR and EFP is inverse, regulatory authorities can redirect individuals' unsustainable remittance-based income toward sustainability by providing incentives for spending a portion of remittance income on green instruments or products. Second, policy formulation and implementation in favor of green investment, green financing, and the use of energy-efficient products may aid in the management of environmental pressures through sustainable financial development. Third, the undesirable effects of technological innovation can be mitigated through favorable financial development in the form of promoting and financing environmentally friendly innovative technologies. Last, improving remote regions may help to reduce rural-urban migration and, as a result, the growing environmental problems.

5.3 Contribution, Limitation, and Future Directions

The present study adds to the literature in a variety of ways. For empirical investigation, the study employs a widely used comprehensive environmental indicator (EFP). It investigates the direct and indirect effects of remittance inflows in a global context to provide broader findings. It improves the methodological application by utilizing panel simultaneous quantile regression. The study is, however, limited to a panel of 94 countries and provides generalized results. Therefore, the study has some future directions as the study can be replicated for different regions, and other proxies of financial development and technological innovation can be used for further in-depth analysis.

Research Funding

Researchers received no research grant or funds for this research project.

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Appendix Table A: List of Sample Countries

Albania	Colombia	Italy	Nigeria	Sri Lanka
Algeria	Costa Rica	Jamaica	North Macedonia	Sudan
Argentina	Cote d'Ivoire	Japan	Norway	Sweden
Armenia	Croatia	Jordan	Pakistan	Switzerland
Australia	Czech Republic	Kenya	Panama	Syrian Arab Republic
Austria	Denmark	Latvia	Paraguay	Tanzania
Bangladesh	Dominican Republic	Lebanon	Peru	Thailand
Barbados	El Salvador	Lithuania	Philippines	Togo
Belarus	Estonia	Luxembourg	Poland	Tunisia
Belgium	Ethiopia	Malaysia	Portugal	Turkiye
Benin	Finland	Mexico	Qatar	United Kingdom
Bolivia	France	Moldova	Romania	United States
Bosnia and Herzegovina	Germany	Mongolia	Russian Federation	Uruguay
Botswana	Greece	Montenegro	Saudi Arabia	Uzbekistan
Brazil	Guatemala	Mozambique	Senegal	Vietnam

Cameroon	Haiti	Nepal	Serbia	Yemen, Rep.
Canada	India	Netherlands	Slovenia	Zambia
Chile	Indonesia	Nicaragua	South Africa	Zimbabwe
China	Israel	Niger	Spain	