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Remittance and Carbon Dioxide Emissions: Does an Environmental Kuznets Curve exist in case of Pakistan?

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ABSTRACT

This research examines the relationship between remittances and environmental degradation in Pakistan by applying the Environmental Kuznets Curve (EKC) hypothesis as a conceptual framework. The study uses the Nonlinear Autoregressive Distribution Lag model in analyzing annual data between 1990 and 2023. The empirical findings show that there is a significant long-run asymmetric impact of remittances on CO_2 emission. The positive remittance inflow increases the emissions, whereas negative ones reduce them, validating the existence of nonlinear environmental effects. The results support the EKC hypothesis in Pakistan, suggesting that remittances initially contribute to environmental degradation however at high-income levels, remittances lead to the enhancement of the environmental quality due to environmental awareness and clean investments. Based on the outcomes, the research suggests policy recommendations, including the promotion of renewable energy investment, the strengthening of environmental regulations, the encouragement of sustainable trade and foreign direct investment (FDI), promote sustainable remittance utilization, the education and empowerment of communities, and the development of institutional capacity to implement green remittance programs. The findings can be applied practically in the realization of environmentally sustainable development in the remittance-dependent developing nations.

Keywords: *Remittances, CO_2 Emissions, Environmental Kuznets Curve, NARDL, Pakistan*

INTRODUCTION

The relationship between remittances and environmental quality has emerged as a significant issue in recent years. On the one side, the remittances are highly praised for their contribution to financial development and poverty alleviation. Besides, their possible environmental implication has received less attention. However, there exists a debate as to how remittances might show an unbalanced relationship with CO_2 emissions **(Ahmad et al., 2019).**

In the past decade, the CO_2 emissions in Pakistan have increased radically **(World Bank, 2023)**. Pakistan, as a developing country, has to face lots of environmental challenges in terms of air pollution, loss of forests, and a shortage of adequate water supplies. Factors such as industrialization, urbanization, and increased

energy consumption have been growing carbon dioxide emissions in Pakistan, which have a relevant impact on climate change.

Recent literature has portrayed the diversified role that remittances play in environmental sustainability in Pakistan. Conversely, it exerts a beneficial impact on the environment by fostering investment in renewable energy and clean technology, as indicated by certain research, while also contributing to environmental degradation through heightened consumption and unsustainable land use practices. For instance, **Khan and Siddiqui (2021)** find that remittances have an effect on reducing the rate of deforestation in Pakistan. Similarly, **Hussain and Khan (2018)** pointed out a nexus between remittances and agricultural expansion in Pakistan, prone to habitat loss. The above arguments create contrasting pictures of the relationship between remittances and the environment for Pakistan. This, no doubt, requires further research to establish how the effect of remittances plays out in terms of environmental results within the country.

Remittances have become an essential economic lifeline to Pakistan as they help maintain household incomes, poverty reduction, and overall growth in the economy **(World Bank, 2023)**. Being countries where millions of Pakistanis work outside their home country in different fields means that over the years, Pakistan has been one of the significant beneficiaries of remittances as thousands of remittance inflows come in whenever there are receivers. **The World Economic Forum (2023)** states that remittances not only provide a significant source of external financing but also play an important role in increasing human development through easier access to education, welfare services, and health in recipient countries. In the example that is Pakistan, these financial transfers have definitely played a significant role in terms of stabilizing the macro-economy and resilience towards social economics. Nevertheless, though the socio-economic impacts of the remittances are widely written about, the environmental impacts, and especially the relation to carbon emissions and rational use of resources, remain underrepresented. This literature gap shows why it is imperative to study whether the consumption patterns, energy consumption, and related environmental degradation can also be carried into the long-term growth in the volumes of remittance inflows.

Problem Statement

Pakistan faces a serious challenge rising levels of carbon dioxide CO_2 emissions driven by economic development and increased energy consumption **(World Bank 2023)**. The CO_2 emission has negatively impacted the environmental quality throughout the nation. According to the Environmental Performance Index (EPI) of Yale University Pakistan stands as the 179th out of 180 countries **WHO (2021)** reports that air pollution in Pakistan annually causes about 130,000 deaths before their time **(Yale University,2024)**. The current ranking system shows major environmental performance issues in multiple aspects. The continuously increasing CO_2 emissions worsen climate change effects while endangering environmental sustainability at its core. These challenges stem from inefficient energy usage together with forest depletion and defective waste disposal systems which significantly intensify environmental degradation **(Pakistan Environmental Protection Agency PEPA, 2020)**. Agricultural productivity decreases along with natural disaster expenses increasing and destructive consequences occur because of biodiversity and ecosystem service losses **(IPCC, 2019; UNISDR, 2015; Millennium Ecosystem Assessment, 2005)**. Health sector services are deeply influenced by environmental degradation because respiratory diseases rise while dangerous pathogens spread and high temperatures cause sickness and death rates escalate **(WHO, 2021; IPCC, 2014; IPCC, 2021)**. **WHO (2021)** reports that air pollution in Pakistan annually causes about 130,000 deaths before their time. Also, Damage to transportation systems, energy infrastructure, and buildings due to extreme weather events **(UNISDR, 2015)**. Moreover, decreased water availability, increased water pollution, and heightened risks of water-borne diseases **(UN Water, 2023)**.

Although remittances or money sent back to Pakistan from the overseas workers funds the economy **(World Bank 2023)**, the environmental effects of remittances are ambiguous. According to some research, remittances can contribute to sustainable development in the form of investing in clean energy and technologies **(Khan & Siddiqui 2021)**. Other research however shows that they might result in enhanced consumption and energy demand, worsening CO_2 emissions **(Ali & Shah 2017, Qadir & Khan 2015)**.

This research attempts to identify the intricate link uniting remittances or CO_2 emissions in Pakistan. Explicitly, trial the applicability of the Environmental Kuznets Curve conjecture, which states that with the beginning arise in environmental deterioration as the economy grows it eventually declines **(Grossman & Krueger 1995)**, to explain the empirical relations between the two variables in relation to the Pakistani context

Research Questions

I. In Is there any impact of remittances on CO_2 emissions?

Objectives of the Study

I. To examine the relationship between remittances and CO_2 emissions in the context of Pakistan.

Research Gap

The ARDL model was used to a large degree in previous studies, and it cannot be used to explain the asymmetric effect of remittances on CO_2 emissions. This research suggests the NARDL method which fills that gap by performing a positive and negative remittance shock analysis separately. This increases the precision and knowledge of remittance-environment nexus in Pakistan.

LITERATURE REVIEW

These are the latest empirical works covering our topic of interest.

Biyase et al. (2024) checked the non-periodic effects of allowance on CO_2 emissions in primary payment-accept countries within the SACU region. Using the cross-section of the CS-ADRL methodology the finding shows that remittance such remittances initially increase CO_2 emissions, but this effect diminishes as remittance inflows rise. This validates an inverted U-shaped relationship these curves are related to CO_2 emissions in the SACU region.

Kuziboev et al. (2024) identified the association between Remittances CO_2 emissions in Central Asian countries (Uzbekistan, Kazakhstan, Kyrgyzstan, and 1 Tajikistan) from 1995 to 2022. Their study employed various econometric techniques, including FMOLS, panel threshold regression, and 2SLS, to address potential non-linearities and endogeneity issues. The results suggest that remittances have a defeatist effect on this test emissions in the long run, indicating that remittances container contribute to environmental sustainability in Central Asia.

Adebayo et al. (2023) investigate the impact of remittances on CO_2 emissions of primary remittance recipient countries from 1990 to 2021. ARDL and Quantile Regression have been used to the empirical analysis. The present investigation is a significant milestone toward ecological sustainability by the findings. The research construct that remittances significantly reduce CO_2 emissions in primary remittance recipient countries.

Ali et al. (2022) investigated the impact of remittances carbon dioxide emissions in Pakistan from 1990-2019. Using the ARDL model, an important positive connection remittances and CO_2 emissions is established over the long run; the growth in remittances adversely affects the environment in Pakistan. This research shows that remittance have boosted the level of CO_2 emissions.

Li et al. (2022) aimed to investigates the environmental collision of remittance inflows in Ghana. NARDL technique have been used to analyses the data. The research finds that remittances to greater CO_2 emissions The study found that remittances contribute to higher CO_2 emissions but noted that technological innovations can enhance environmental quality. There is direct cause and effect between remittances and CO_2 emissions.

Ahmed et al. (2019) investigated potential asymmetric transmissions from remittances to carbon dioxide emissions in China using time series data from 1980 to 2014.

The long-term imbalance link jointly remittance inflows and carbon emissions are inspect using the Non-linear NARDL technique. The finding presents that while a negative impact on remittances caused CO_2 emissions to decrease, a positive boost to payment causes greenhouse gases to rise. Both in the short and long haul they reveal an uneven cointegrating relationship between remittances and CO_2 emissions.

Zhang et al. (2020) identified the environmental effect of remittances in top remittance-receiving countries between 1990 and 2018. The research that remittances positively impact ecological impression. The study EKC hypothesis for some countries, indicating a potential decline in environmental degradation with economic growth. Through for others, a U-shaped connection suggests increasing environmental pressure with development. The results demonstrate why economic development needs to harmonize with environmental sustainability across such nations.

Wang et al. (2021) conducted research on how remittances influence CO_2 emissions across India, the Philippines, Egypt, Pakistan and Bangladesh during 1980 to 2016. The research conducted showed that foreign currency transfers from migrants have a significant impact on lowering carbon dioxide emissions. The findings demonstrate they intricate pattern between immigration funds and economic expansion and sustainable environmental practices in these particular nations.

Shahid et al. (2023) analyzed the sophisticated connection between remittances and CO_2 emissions in multiple countries that possess both digitalized and established economic systems. A research investigation sought to fill the knowledge gap about the public perception-CO_2 emission association. The study conducted its analysis using modern econometric analysis to show remittances act as an environmental sustainability tool through emission reduction yet economic expansion generates increased environmental damage.

Brown et al. (2020) demonstrated how environmental degradation shows an inverted U-shaped pattern which depends on economic development levels. The study employed time series data from 1976 to 2014, employing autoregressive distributed lag bounds testing methodologies to elucidate the causal relationship between these factors. Two principal findings exist, long time period cointegrating jointly from remittances carbon dioxide earning. Secondly, they provide substantial investigate of an asymmetric reaction of CO_2 to fluctuations in remittances exclusively in the short term.

Yang et al. (2020) studied the upshot of remittances on CO_2 emissions utilizing a global sample of 97 nations from 1990 to 2016. The principal findings, derived from a rigorous system GMM (Generalized Method of Moments) analysis, reveal that remittances elevate CO_2 emissions. These results were uniform across both industrialized and developing nations.

Along similar lines, Neog et al. (2020) tried to find out the asymmetric relationship between remittances and carbon dioxide emissions in India for the period of 1980 to 2014.This research used NARDL model for the time series analysis. The finding of the study shows the expanse of asymmetric long-run association among the variables. The outcomes reveal that the remittances significantly lowered the carbon emissions in India.

Islam et al. (2023) examined the asymmetric impact of remittances on environmental quality in the top 20 remittance-earning nations. The study used panel data from 1996 to 2020 and conducted the estimation method and the Dumitrescu-Hurlin causality test. The research findings suggest that remittance inflows have significant and asymmetric results on each economic growth and ecological quality. Additionally, the study found that energy use, financial development, and regular standard positively affect economic growth. While economic development, regulatory quality, and GDP are approving for the environment.

Akinlo et al. (2022) investigates the asymmetric relationship between remittances and environmental degradation in Nigeria (1980-2018). While remittances offer economic benefits, their environmental impact

is a growing concern. The study uses the NARDL approach to analyze how increases and decreases in remittances affect environmental degradation. Findings reveal a long-run connection between remittances and environmental measures (ecological footprint and CO_2 emissions). Notably, remittance increases contribute to environmental degradation in the long-term, with an asymmetric impact observed in both short and long run for ecological footprint and only long run for CO_2 emissions.

Khan et al. (2022) identified factors determining carbon dioxide emissions, focusing on the role of remittances in combination with economic growth, financial development, and energy consumption, accounting for four selected G-20 economies for the period from 1990 to 2019. The unit root model can be employed to analyze and evaluate negative and positive changes the variables and their short-run haul and long-run relationships. Financial development positively correlates with both Mexico and India's CO_2 emissions, though the effects of remittances and renew energy on emissions differ. This report thus advises G-20 nations to ensure that financial and progress does not compromise environmental conservation in respect of pollution.

Zafar and colleagues (2022) analyzed environmental outcomes from remittances together with export diversification steps, educational initiatives and renewable energy adoption and economic growth patterns in major remittance recipient states throughout the years 1986 to 2017. The research data demonstrated that payments sent home and export market expansions coupled with renewable power usage led to Carbon dioxide emission reductions. Taxing economic growth together with education led to more carbon emissions. Research findings present policymakers with valuable knowledge about the intricate economic development and environmental sustainability interactions.

Elbatanony et al. (2021) analyzed the environmental changes that occur when low- and middle-income countries receive remittance payments throughout the period from 1980 to 2014. This research applied a modified Environmental Kuznets Curve (EKC) hypothesis through method of moments quantile regression analysis. The research indicates remittances produce non-uniform environmental effects on CO_2 emissions. This research demonstrated that remittance inflows in lower-middle-income countries produce an inverted N-shaped pattern with CO_2 emissions since higher remittance levels support the development of cleaner energy patterns. Remittances in upper-middle-income nations produce environmental effects which vary based on how developed their economies are.

Awodumi and Adewuyi (2020) examined how petroleum together with natural gas consumption affects African oil-producing economies through their growth and carbon emissions during the period from 1980 to 2015. This study used the NARDL model to discover asymmetric effects throughout various countries because positive non-renewable energy consumption changes generated simultaneous economic development as well as rising emissions. The fluences from decreases in energy consumption produced different results across the examined cases.

Theoretical Framework

This study is based on the theoretical framework resting on the EKC speculation. EKC is a hypothesis that views the economic growth and environmental humiliation in an inverted-U-curve connection. The theory suggests that an increase in economic growth initially results in higher pollution levels; however, after reaching a certain threshold, continued growth contributes to a reduction in pollution due to advancements in technology and the implementation of effective policies. As revenues rise, nations are likely to adopt cleaner technologies, implement stricter environmental regulations, and consequently lower emissions **(Stern, 2017)**.

This framework is highly applicable to the understanding of how economic growth affects environmental follow-up in the time perspective. The counterpart remittance theory, on the other hand, examines the financial flows that rather send to their home countries and their social and economic consequences. Although remittances can revitalize local economies by boosting consumption and investment, for all that, they might be associated with is raised demand for carbon-intensive goods and services, thus exacerbating environmental problems in the case of developing nations. This study goal to calculate the effect of earning

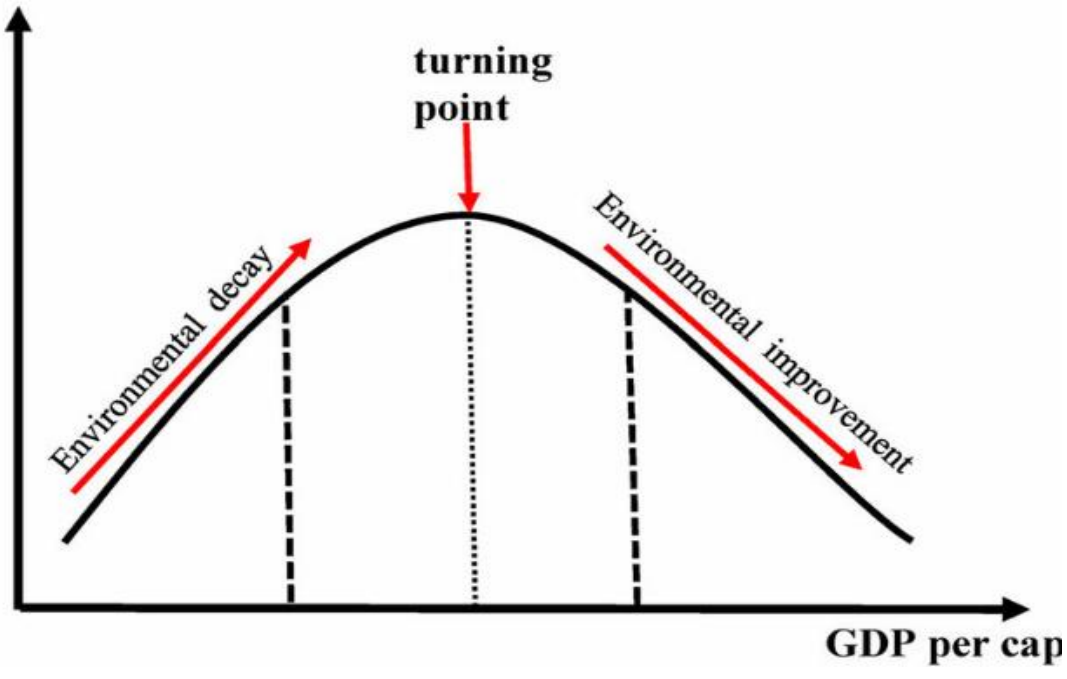
inflows on CO_2 emissions across various stages of economic development in Pakistan by merging these two hypotheses. They hypothesize that while remittances might in the short-term increase emissions to strengthen a consumption pattern, they would also enable investment in endurable execution once the economy matures. The integration of EKC and remittance theory provides an expanded bifocal through which to examine the complex energetic allying economic growth driven by remittances and environmental stability. This framework, though leading the way for empirical analysis, provided potential policy interject focus on overestimating the positive impacts of remittances spent mitigating their environmental termination. This study will therefore add valued awareness to sustainable development strategies in Pakistan and underline the need for policies that encourage cleaner technologies at the forefront of economic growth powered by remittances. It is postulated and supported through some available literature on the EKC hypothesis and theory of remittances, which identifies it very relevant to understand the relationship between them in the frame of developing economies like Pakistan.

Environmental Kuznets Curve (EKC)

The hypothetical link between economic development measured using GDP per capita alongside environmental shame appears in Figure [3] as an Environmental Kuznets Curve. The inverted U-shaped curve presents information about how environmental degradation rises in start point of economic expansion because of industrialization and urbanization and reliance on fossil fuels. The rapid growth phase in environmental degeneration is named “environmental decay.” The ongoing income rise in economies leads to a "turning point" which enables environmental awareness together with stronger regulations and cleaner technologies to diminish environmental degradation. The “environmental improvement” phase represents the moment when enhanced economic sustainability generates environmental benefits at higher income levels **(Dinda, 2004)**.

The analytical framework works perfectly for understanding how remittances affect carbon dioxide (CO_2) emissions levels in Pakistan. When household income rises because of remittances there follows an initial consumption surge and energy usage increase that both harm the environment. The country can advance towards diminished emission levels through sustainable practices supported by suitable policies and investments in clean technologies provided by remittances. The research supports the hypothesis that remittances generate an inverted U-shaped influence on environmental quality in Pakistan in accordance with **Dinda (2004)**.

Fig 1: Environmental Kuznets Curve



Methodology Data Sources

For this study, the data are collected from the World Development Indicators. The dataset begins from the year 1990 to 2023, with a wide variety of significant variables that describe their association with remittances and CO_2 emissions. The most important variables are GDP per capita, renewable energy consumption, foreign direct investment, financial development, and trade openness. This huge dataset allows a strong analysis of (EKC) hypothesis related to Pakistan's remittances and environmental consequences.

Methodology Used

This research uses the (NARDL) model to analyze the correlation interlinkage remittances and CO_2 emissions in Pakistan. The model enables us to analyses the quick dynamics and the long-run dynamics as well as the interrelationship between the variables whilst taking into consideration the possibility of various asymmetries in the effect of non-empirical results disturbance in remittances. The model also features control variables in the form of consumption of renewable energy (REC), foreign direct investments (FDI), financial growth is able to (FD) trade openness (TR) and GDP in order to know their effect on CO_2 emissions.

Specification of Model Dependent Variable

Metric tons of CO_2 emitted per head of population: Carbon dioxide emissions entail releasing the carbon gases into the situation through the combustion of fossil fuel like coal, oil, and natural gas. CO_2 emissions, the key indicator of deterioration of environment and global warming, are measured in metric tonnes per capita. Within the scope of this study, CO_2 emissions are the DV to determine whether the EKC hypothesis applies to Pakistan, looking at the influence of the economic variables such as remittances on environmental consequences over time.

Independent Variables

Remittances (% of GDP): Remittance means the personal transfer and compensation to employees from the abroad coming to the residents. As a proportion of GDP, remittances are one is viable sources of external economic g in the developing economies such as Pakistan. They can have direct effects on environmental consequences such as changing people's consumption patterns and indirect ones such as raising income that might change energy utilization and environmental behavior. Their effect on CO_2 emissions can be significant or negative, depending on the way the funds that are received will be spent – for example, on consuming energy-demanding products or the development of less pollution-creating technologies

Renewable Energy Consumption (as a % of Total Final Energy Consumption): They give the share of renewable sources, i.e. solar, wind, hydro, biomass, in the total final energy consumption. Greater consumption of renewable energy is also seen as the decreased emitted greenhouse gasses and the shifting of sustainable development trajectory. Renewable energy consumption was expected to a negative linkage with the CO_2 emissions, which would contribute towards the improvement of environment and may facilitate the decline of EKC.

Foreign Direct Investment (FDI) Inflows (%) of GDP: FDI is investment in private business or production by outside force. As a percentage of the GDP, FDI inflows can support the development of the economy and development of technologies. However, the impact of their environment is dependent upon the nature of investment. FDI in industries which pollute may raise the level of emissions, whereas FDI in clean technology projects can decrease it. Hence, the impact it has on CO_2 emissions in Pakistan is an empirical question, which should be investigated.

Financial Development (Domestic Credit to Private Sector (% of GDP: Economic development is usually calculated in widening of credit extended to the individual sector percent of GDP. A more robust economic system will help investments in cleaner and productive technology. Nevertheless, an improved availability in credit could fund consumption and industrial expansion causing more emission. In the present study, the financial development is incorporated to see its dual impact on economic advancement and environmental exertion.

Trade Openness (% of GDP): The measurement of trade openness is given the summation of the exports and bring and its percentage to economic growth. Higher degree of trade liberalization can result in either positive or negative outcomes in terms of environment. On the one hand, it can trigger technology transfers and the access to the cleaner goods. On the other hand, it might cause pollution by increased production and transportation. This variable is incorporated in order to understand net impact of trade on CO_2 emissions for Pakistan.

GDP per Capita: GDP per capita is the indicator of income per person of an economy and it indicates the economic development level of an economy. It is right in the core of the Environmental Kuznets theory that predicts that there exists an inverted-U relationship between income and environmental damage. Low-income levels are such that economic growth enhances pollution but at a certain level, the further economic growth might well cause improvements in the environment through improved regulations and cleaner technology.

Estimation Technique and Results Estimation Method

Long-Run Equation

The long-run relationship between CO_2 emissions and the independent variables is captured by the following equation:

$$CO2_t = \alpha_0 + \lambda_1 REM_{t-1} + \lambda_2 REM_{t-1} + \lambda_3 REC_{t-1} + \lambda_4 FDI_{t-1} + \lambda_5 FD_{t-1} + \lambda_6 TR_{t-1} + \lambda_7 GDP_{t-1} + \lambda_8 CO2_{t-1} + \mu_t$$

Where:

- **CO_{2t}** represents carbon dioxide emissions at time t,
- **REM+** and **REM−** are the positive and negative changes in remittances, respectively,
- **REC** is renewable energy consumption,
- **FDI** is foreign direct investment,
- **FD** is financial development,
- **TR** is trade openness,
- **GDP** is gross domestic product per capita,
- **CO_{2t-1}** is the lagged dependent variable, included to capture the long-run effects and ensure cointegration,
- **μt** is the error term.

Short-Run Equation

The short-run dynamics are modeled by incorporating first differences (Δ) of the variables, as well as an error correction term (ECT) to modify for any disequilibrium. The short-run equation is given by:

$$\Delta CO2_t = \alpha^0 + \sum_{j=1}^{p} \beta^{1+} \Delta REM^{+}\{t-j\} + \sum_{j=1}^{p} \beta^{1-} \Delta REM^{-}\{t-j\} + \sum_{k=1}^{q} \beta^{2} \Delta REC\, t-k + \sum_{l=1}^{r} \beta^{3} \Delta FDI\, t-l + \sum_{m=1}^{s} \beta^{4} \Delta FD\{t-m\} + \sum_{n=1}^{u} \beta^{5} \Delta TR\{t-n\} + \sum_{o=1}^{v} \beta^{6} \Delta GDP_{(t-o)} + \varphi\, ECT\_\{t-1\} + \varepsilon t$$

Where:

- **Δ** represents the first difference operator, used to model the short-Term changes in each variable,
- **β1+ and β1−** capture the consequence of the positive and negative changes in remittances on CO_2 emissions in the short run,
- **ϕ** is the coefficient of the error correction term (**ECT**), which measures the speed at which any disequilibrium in the short-run is corrected towards the long-run equilibrium,
- **ϵt** is the error term.

Explanation of the Model

The NARDL model separates the remittance variable into positive and negative changes to look at whether remittances have the asymmetry effect on CO_2 emissions. The incorporation of the error-correction term (ECT) into the short-run equation enables the model to put short-run imbalances between variables into place hence convergence to a long-run equilibrium. The long-run equation describes the steady state correlated between the variables, while the short-run equation accounts for the changes over the period of time.

By estimating these equations, the current study intends to determine if remittances, with the other control variables, determine significant changes in CO_2 emission in Pakistan; both in the short and the Empowering Women, Transforming Economies Rasool, Rahman, Akram & Batool

long run.

RESULTS

Table 1: Descriptive Statistics

Variable	Mean	Median	Max	Min	Std. Dev
CO_2	0.704619	0.711122	0.918473	0.505906	0.103336
REM	4.469704	3.578471	8.984363	1.080567	2.142447
REC	48.52132	47.65	58.1	41.6	4.535542

FDI	0.927744	0.695727	3.035719	0.309595	0.657867
FD	19.28386	18.75352	25.47432	11.97679	4.29225
TRADE	30.68152	31.10462	38.49932	21.45997	4.728215
GDP	1.624457	1.500378	5.202456	-3.03889	2.110024

The descriptive statistics for the variables conducted in this research, give a comprehensive overview of their tendencies and dispersion over the period of 1990 to 2023. The main dependent variable, CO_2 emissions (CO_2), measured in metric tons per capita, exhibits a mean of 0.704619, with a standard deviation of 0.103336. This indicates a moderate level of variability in CO_2 emissions during the study period.

Remittances (REM), is also present the percentage of GDP, show a mean of 4.469704, suggesting a significant contribution to Pakistan's economy. However, the standard deviation of 2.142447 indicates considerable fluctuations in remittance inflows over time. Renewable energy consumption is used proxy as a percentage of total final energy consumption, has a high mean of 48.52132, reflecting a substantial reliance on renewable energy sources. Foreign direct investment (FDI), as a percentage of GDP, has a low mean of 0.927744, suggesting relatively modest FDI inflows. Financial development proxied by private credit to the individual sector as a percentage of GDP, has a mean of 19.28386, indicating a moderate level of financial sector development. Trade (TRADE), also expressed as a percentage of GDP, displays a mean of 30.68152. Economic growth (GDP), measured as GDP per capita, has a mean of 1.624457. The GDP variable also shows a minimum value of -3.038893, suggesting that there were periods where the economy contracted.

Table 2: Unit Roots

Variable	ADF (Levels)	ADF (1st Difference)	PP (Levels)	PP (1st Difference)	Order of Integration
CO_2	0.4643	0.0019	0.4592	0.0004	I (1)
REM	0.9464	0.0016	0.9064	0.0001	I (1)
REM+	0.9688	0.0003	0.9991	0.0000	I (1)
REM-	0.2391	0.0002	0.2302	0.0002	I (1)
REC	0.5607	0.0000	0.4858	0.0000	I (1)
FDI	0.0385	0.0063	0.3243	0.0087	I (1)
FD	0.7067	0.0004	0.7067	0.0004	I (1)
TRADE	0.2921	0.0000	0.2709	0.0000	I (1)
GDP	0.0022	0.0000	0.0022	0.0000	I (0)
GDP^2	0.0042	0.0000	0.0042	0.0000	I (0)

The Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests of unit roots were applied to all the variables, including decomposed remittance components (REM+ and REM-) and the squared GDP term (GDP_SQ), depending upon which the results obtained are summarized in Table 5. The results indicate that CO_2 and six other variables, viz, REM, REM+, REM-, REC, FDI, and FD, are non-stationary at the level and are stationary at the first difference, implying they are I (1). ADF and PP tests revealed in the case of

CO_2 that p-values were higher than 0.05 at level, indicating non-stationarity, whereas first differences indicated a p-value lower than 0.05, which indicates the stationarity. On the other hand, the GDP and GDP_SQ were also determined to be level I (0) because both p (p = 0,000) values were significant based on the two tests. The combination of I (0) and I (1) variables favor the appropriateness of the NARDL model because none of the variables should be of order I (2) or beyond.

Table 3: Short-Run Coefficients of the NARDL Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D (CO_2 (-1))	-0.080691	0.095250	-0.847151	0.4075
D(REM_POS)	-0.004213	0.006745	-0.624551	0.5397
D (REM_POS (-1))	-0.020338	0.005924	-3.432965	0.0028
D(REM_NEG)	0.029490	0.011222	2.627826	0.0166
D(REC)	-0.020253	0.002513	-8.059533	0.0000
D(FDI)	0.002726	0.007034	0.387551	0.7027
D(FD)	0.005553	0.002289	2.426406	0.0254
D(TRADE)	-0.004073	0.001445	-2.818484	0.0110
D(GDP)	0.006590	0.001549	4.253419	0.0004
D (GDP (-1))	0.005542	0.001409	3.933569	0.0009

In the short-run estimation, the lagged dependent variable D (CO_2 (-1)) fails to acquire statistical significance, implying that the effects linked to previous years regarding carbon emissions do not possess any significance of immediate importance in the concise-run dynamics. Zero significant impact on CO_2 emissions was also found in initial changes in positive remittance inflows (D(REM_POS)). This fact demonstrates that immediate changes in remittances may not cause direct effects in terms of changing the environment. Nonetheless, lagged negative changes in remittances (D (REM_POS (-1))) also have a significant adverse effect on CO_2 emissions, which means that a fall in remittance inflows in a lagged period has a significant negative impact on the reduction in environmental degradation. However, on the contrary, there is a substantial statistically significant increase in CO_2 emissions over the short-run measures of positive remittance shocks, implying that the boost in consumption and economic activity in the economy due to remittances might aggravate the pressure on the environment.

Table 4: Bounds Test for Cointegration

Null hypothesis: No levels relationship
Number of cointegrating variables: 8
Trend type: Rest. constant (Case 2)
Sample size: 31

Test Statistic	Value
F-statistic	27.903503

	10%		5%		1%	
Sample Size	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
30	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
35	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
Asymptotic	1.850	2.850	2.110	3.150	2.620	3.770

*** Finite sample critical values are valid up to 7 error-correction variables.

The calculated F-statistic is 27.903503. The required censorious values for the bounds test originate from analysis of 8 variables in the model. Our study finds that the calculated F-statistic surpasses both critical values at the 1% significance level. The null hypothesis gets rejected because confirm the existence of a statistically significant long-run connections between CO_2 emissions, remittances, renewable energy consumption, foreign direct investment, financial development, trade, and GDP in Pakistan.

Table 5: Long Run Results

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D (REM_POS (-1))	-0.022718	0.007535	-3.014827	0.0064
D(REM_NEG)	0.027288	0.010729	2.543280	0.0185
D(REC)	-0.018741	0.002854	-6.566170	0.0000
D(FDI)	0.002522	0.006511	0.387417	0.7022
D(FD)	0.005138	0.002090	2.458048	0.0223
D(TRADE)	-0.003769	0.001354	-2.784286	0.0108

D (GDP (-1))	0.011226	0.002599	4.320155	0.0003
D(GDP_SQ)	-0.001619	0.000419	-3.862651	0.0008
C	0.013762	0.004320	3.185595	0.0043

Research shows that positive changes in remittances that occurred in the past provide negative effects on CO_2 emissions. Declines in remitter flows create positive influences on carbon dioxide emissions throughout the long-term perspective.CO_2 emissions experience negative effects when renewable energy consumption increases. The expansion of financial activities produces beneficial effects on CO_2 emission levels. Emissions of CO_2 decrease because of trade activity. The results show GDP with GDP square variables prove the Environmental Kuznets Curve during the long-run stage.

Table 6: Error Correction Term

Variable	**Coefficient**	**Std. Error**	**t-Statistic**
COINTEQ	-1.080691	0.053293	-20.2783
D(REM_POS,2)	-0.004213	0.003074	-1.370348
D(GDP,2)	0.00659	0.000612	10.76632
Variable	Coefficient	Std. Error	t-Statistic
COINTEQ	-1.080691	0.053293	-20.2783

Interpretation of ECM Results: Test finding present that the error correction term coefficient stands at -1.0807.

Sign and Significance: The negative coefficient shows both theoretical consistency and strong statistical significance at p=0.0000 which confirms the binding cointegration found during the bounds test. The model demonstrates equilibrium restorations that operate throughout time periods.

Magnitude (Speed of Adjustment): This number demonstrates the rate at which systems return to their equilibrium state. The value of -1.0807 shows that the system adjusts 108.1% of the previous period's disequilibrium during the current period. The exceptionally fast adjustment (greater than 100%) implies an unstable but rapid movement toward attaining the long-run equilibrium. The model's high speed of adjustment could lead to concerns about either data specifications or modeling structures that need further evaluation.

Short-Run Dynamics: The short-run ECM analysis shows D(GDP,2) produces significant positive impacts but D(REM_POS,2) causes no significant effects.5.7Diagnostic Tests

To ensure the robustness and reliability of the NARDL model, several diagnostic tests are conducted. These include tests for heteroskedasticity, serial correlation, non-normality, and model stability.

Table 7: Heteroskedasticity Test

F-statistic	1.458239	Prob. F (11,19)	0.2267
Obs*R-squared	14.19094	Prob. Chi-Square (11)	0.2226
Scaled explained SS	4.894833	Prob. Chi-Square (11)	0.9362

The results indicate that the p-values for all three test statistics are greater than 0.05.

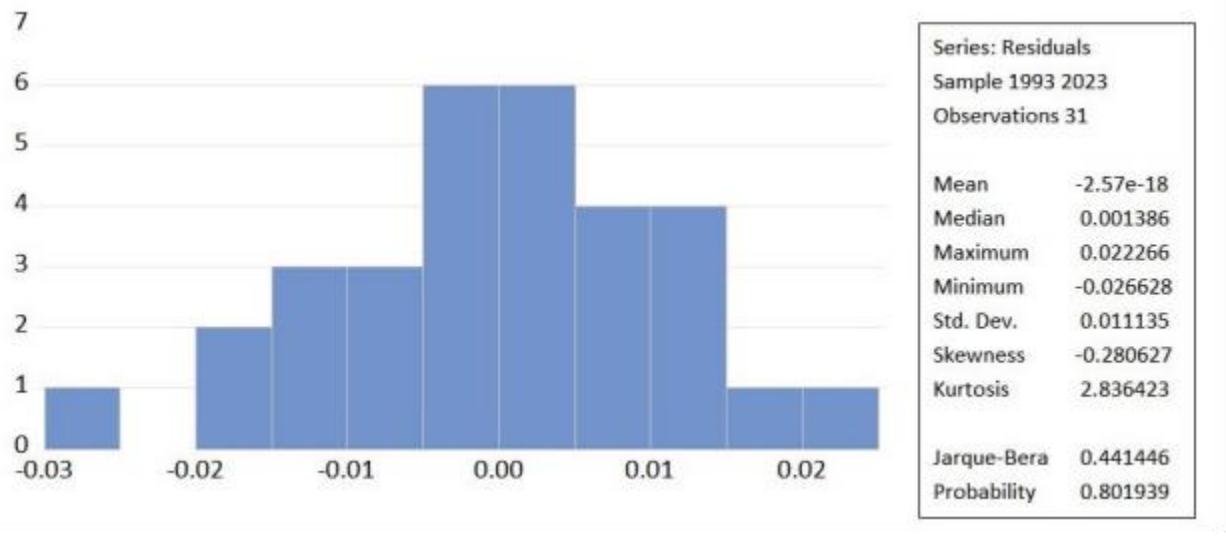
From these results cannot deny the null hypothesis which led toward to the conclusion that heteroskedasticity does not exist significantly within the model.

Table 8: Serial Correlation

F-statistic	1.013551	Prob. F (2,17)	0.3838
Obs*R-squared	3.302666	Prob. Chi-Square (2)	0.1918

The statistical p-values obtained from both tests exceeded 0.05. Our evidence points toward accepting the null hypothesis which indicates that the model shows no statistically important serial correlation effects.

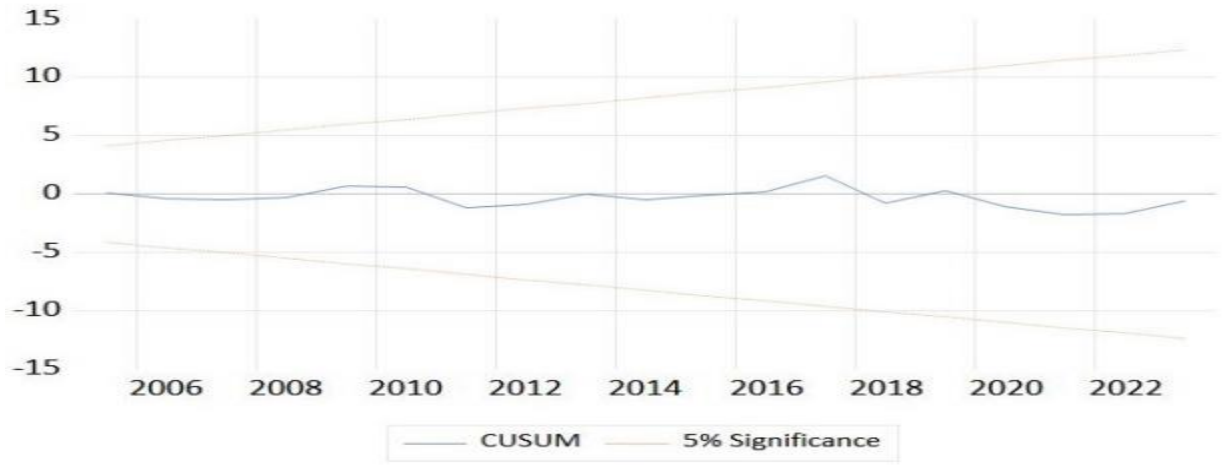
Fig 2: Normality Test



The Jarque-Bera test evaluates to 0.801939 exceeding the significance level of 0.05. Studies show that should not reject the hypothesis that the data are normally distributed. The residuals display approximately normal distribution. According to the histogram results the residuals form a bell curve that lies roughly at zero.

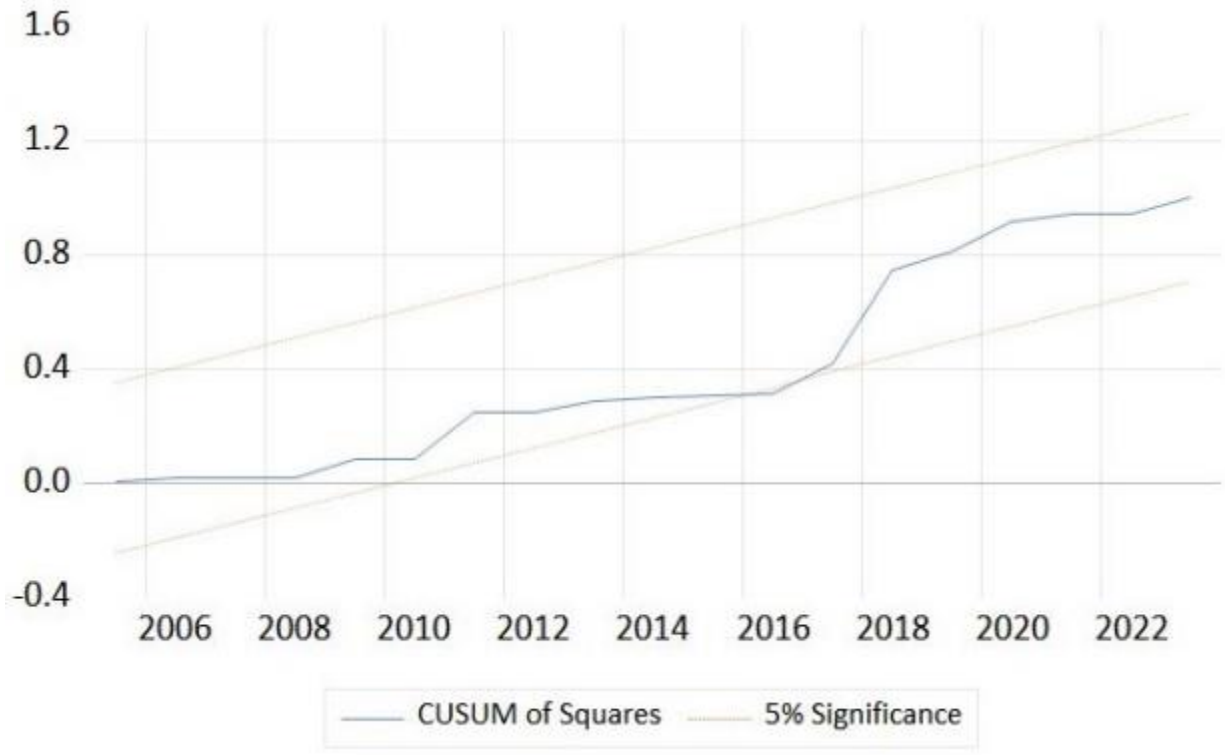
Stability Test

Fig 3: Cusum Test



This graph, illustrating the CUSUM (Cumulative Sum) test, displays a blue line that represents a CUSUM statistic between two dashed orange lines that represent the critical bounds at the level of 5 percent. The CUSUM line stays within these limits. This finding implies that the coefficients of the model remain steady over time, and consequently, no significant systematic changes in the parameters took place and, therefore, confirm the validity of the estimated relationships in this period of time.

Fig 4: Cusum Square Test



As shown in this Figure, the CUSUM of Squares test contains a blue curve of the cumulative sum of squares of recursive residuals versus the exact limits of critical values (5%). In spite of the fact that the CUSUM of Squares line still stays within the critical limits in the greater part of the period, it is significantly in excess of the upper critical limit of the final years, including 2020 and after, particularly. Such a violation means that after the mid-period of the study time, there was structural breakdown or instability in the model parameters, and therefore, the relationships between the variables might have been changed somewhat to some extent at the completion of the study time period.

CONCLUSION

This study aimed at investigating asymmetric influence of remittances on carbon dioxide (CO_2) emissions in Pakistan between 1990 and 2023 by using the Nonlinear Autoregressive Distributed Lag model. The research was to provide a test to the Environmental Kuznets Curve (EKC) hypothesis, which holds that a product of economic growth and environmental degradation is inverted U-shaped relationship. Through the current study, the overall impact of remittance inflows (positive and negative inflows) on environmental outcomes in Pakistan has been established. The research has started by providing an in-depth background of the issues surrounding the development-environment relationship and the related role that remittances are taking to influence this relationship in developing economies. It found a large gap in existing literature whereby the past studies have not been able to capture the asymmetric effects of remittance flows. Majority of the previous studies used linear models and they ignored the nonlinearity that is presented in the economic-environmental relationships in practice.

This was proceeded by an extensive literature review and mapping the empirical findings across countries and approaches of analysis and setting the requirements of further investigation in the Pakistani context through a nonlinear framework. It was discovered that while some studies suggested remittances harm the environment through increased consumption, others highlighted their role in reducing poverty and enabling green investments. This dual nature emphasized the need for this study's empirical contribution.

The theoretical foundation of the study linked remittance flows and economic growth with environmental outcomes through the lens of the EKC. The model framework incorporated relevant macroeconomic variables—remittances (both positive and negative shocks), renewable energy consumption, foreign direct investment (FDI), financial development, trade openness, and GDP per capita—to comprehensively explore their combined effect on CO_2 emissions.

A panel of robust econometric tests and modeling was conducted in the methodology chapter. Using annual data from 1990 to 2023, the study established the mixed order of integration among the variables, with GDP and GDP^2 being stationary at level and other variables stationary at first difference. The NARDL model was selected due to its suitability for this integration structure and its ability to capture short- and long-run asymmetries.

The empirical findings revealed that remittances do not affect the environment uniformly. Positive remittance shocks, particularly with a lag, were found to significantly reduce CO_2 emissions—likely through environmentally conscious investments and improved access to renewable technologies. Negative remittance shocks, on the other hand, increased CO_2 emissions in both the short and long run, suggesting that reductions in remittance flows can hinder sustainable consumption and lead to reliance on carbon-intensive alternatives. The Environmental Kuznets Curve hypothesis was confirmed for Pakistan: initially, economic growth increased emissions, but after reaching a turning point, further growth led to a decline in emissions. This validates the potential for sustainable development through economic advancement.

Renewable energy consumption emerged as a consistently negative and significant factor in both short- and long-term models, affirming its role in reducing CO_2 emissions. Financial development, while facilitating economic growth, showed a positive correlation with emissions, highlighting the need for integrating green finance and environmental safeguards into the financial sector. The level of trade openness was actually discovered to diminish emissions, probably because of importation of cleaner technology and impact of environmental requirements of the trading partners.

All the important diagnostic tests conducted were analyzed and the model passed serial correlation, heteroskedasticity, and normality tests. The stability of the model was confirmed using the CUSUM test, and the model is structurally stable with the exception of the recent years based on the CUSUMSQ test, possibly because of the economic shock or policy changes.

Based on the overall findings the study comes to the conclusion that remittances in Pakistan are a two-edged sword, they can either contribute or lead to destruction of environmental sustainability depending on the way one directs them. When guided appropriately, they can finance green energy, greener transport and sustainable homes. Unless they are controlled, there is a chance that they contribute to unsustainable consumption patterns.

The study has greatly contributed to the novelty by utilization of the NARDL model in order to reveal these asymmetric effects. It stresses that a fine-tuned policy is necessary that can ensure a maximum positive impact of remittances on a positive environmental environment and reduce the negative one. Environmental factors have to be considered in future economic plans so as to have a sustainable economy. The results support the necessity of policy consistency between economic planning, financial flows, and environmental management, and they place the remittances beyond being a source of financial assistance but also tools of ecologic resilience and green development.

Policy Suggestions

The following policy measures should be taken:

- **Promote Sustainable Remittance Utilization**

The government of Pakistan shall formulate policies that reinforce the investment of the recipient of remittances to green sectors and this shall make the remittances to be beneficial to nature. This can be done by introducing fiscal incentives, in terms of tax rebates or lower tariffs, on the remittance backed investments on renewable energy plant, sustainable agricultural and energy efficient building construction.

Special financial instruments are to be created including green remittance bonds, diaspora green savings account and remittance-linked impact funds. These tools have the capability of aggregating the diaspora funds to finance environmentally friendly activities. This is because policymakers should employ transparent laws and mechanisms to guide these investments to make them safe and reliable by the investors.

In addition, education programs via embassies, community centers and online will have to be introduced to make overseas workers and their families aware of the opportunity of taking up remittances in support of climate action. Remittance of spending can be incorporated into financial literacy provided by remittance service providers through training modules on sustainable spending.

- **Enhance Renewable Energy Adoption**

Pakistan has immensely great solar, wind and hydro potential energies that remain unexamined. National energy and environmental strategy must have a strategic thrust towards renewable energy. There should be policies aimed at ensuring that there is enabling environment of renewable energy investment both by the domestic and foreign investors.

This involves putting in place attractive feed-in tariffs, simplifying the licensing procedures, cutting down red tapes, and introducing some tools to curb the risks like credit guarantees to a solar or wind project. The government can as well establish green energy investment zones in the rural areas where many people receive remittances.

Households can be assisted to co-finance the cost of micro-hydro solutions, efficient cooking stoves and premium solar panels through the use of subsidy programs. Remittance institutions could also be given the

role of loan guarantees funding developments of renewable energy through the establishment of public-private partnerships with remittance institutions.

- **Foster Green Financial Development**

Financial system assumes a major role in the direction of investments. Financial regulators should come up with systems to incorporate the Environmental, Social, and Governance (ESG) standards into lending and investing policies. There should be environmental impact assessment that commercial banks must undertake before issuing large scale loans.

Green financial products like climate bonds, green insurance and eco-loans need to be extended with effective incentive support. In example, the banks may provide discounted interest rates on loans on energy efficient structures or on electrical vehicles that will be bought by the funds obtained on remittance level.

One of the things that also should be provided by the State Bank of Pakistan is the incentives to financial institutions that hit some of the green lending marks. creation of a centralized Green Finance Task Force by the central bank would allow tracking the progress situation and coming up with more innovative tools.

- **Strengthen Environmental Governance**

It should have a proper environmental policy framework that can be enforced in order to check on the emission of gases and environmental degradation. It is important to improve the institutional capacity of Pakistan Environmental Protection Agency (PEPA). It should be armed with advance monitoring technologies, data analytics, and implementation mechanisms.

All construction or commercial projects that have been brought about by remittances must be subject to conducting the Environmental Impact Assessment (EIA). A stick-to-it-iveness and regularity of audits are well able to dictate the integration of environment in each development phase.

One approach is to gradually introduce carbon taxation or cap and trade as well, starting with the high-emission sectors. The revenue generated can be set aside in order to finance eco-friendly infrastructure development such as tree plantation, eco-parks, and urban-mobility schemes.

- **Encourage Sustainable Trade and FDI**

Pakistan needs to review its trading and FDI policies in order to make them conform to environmental aspects. Green technologies and green services should also be imported into a country at a rate that is facilitated by trade policies. The companies that use environmentally friendly packaging, cleaner methods of transport and power efficient operations can be accorded preferential treatment.

The environmental clauses should be in the agreement between the investors, and humankind will be required to take green actions. It could be set with the introduction of Eco-Industrial Parks (EIPs) in special economic zones where only sustainable industries are involved.

Promoting firms within waste-to-energy, electric mobility, and renewable energy supply chain can be implemented as Green FDI promotional strategies. Fast-track approvals and lower-duties should also be used as incentives to attract such businesses.

- **Build Institutional Capacity for Green Remittance Programs**

The Ministry of Climate Change should set up a permanent unit so as to organize green remittance strategies. This body is to collaborate with the ministry of finance, the State Bank of Pakistan and remittance channels to draft and execute policy.

It must have a central dashboard to monitor the origin, transmission, and use of remittances which have an

impact on the environment. The policy targeting and transparency will be facilitated by data that is disaggregated by area, industry and investment use.

It is also possible to use this organization as a source of knowledge on best practices, provide grants or seed money to pilot projects, and create development partnerships with international development organizations.

- **Educate and Empower Communities**

Sustainability demands behavioral transformation so as to go green. As thus, the communities that receive remittances ought to be made aware of the future implications of their consumption patterns. Workshops and seminars should be organized at the local level and by NGOs and schools to discuss the subjects like energy saving, trash reduction, water consumption, and green business.

Moreover, climate education can be availed in the school studies, and in particular in high remittance areas, which will spread awareness among the younger generation and develop climate friendly culture. Green knowledge can further be democratized through mobile applications, online education, and SMS campaigns. To be open and accommodative, these tools can be formatted to include languages used in the area and cover as many people as possible.

- **Leverage International Cooperation**

The remittance and climate-related programs should be in line with Pakistan commitments of international frameworks that include the Paris agreement and the SDGs. International agencies such as the World Bank, UNDP, ILO and IOM should be used to offer technical help and financial assistance. Diaspora engagement activities can establish networks through which the overseas Pakistani can communicate innovations, invest in climate-resilient projects, and guide green venture firms. Such partnership may be facilitated by the Pakistani embassies and consulates. Moreover, bilateral agreements with the leading host nations (e. g. the UAE, Saudi Arabia, the UK, the USA etc.) may involve the stipulation of environmentally friendly mechanisms of remittance investment.

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