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DOES RENEWABLE ENERGY CHANGE THE REMITTANCE-CARBON EMISSIONS NEXUS? EVIDENCE FROM SELECTED ASIAN ECONOMIES

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KEYWORDS	ABSTRACT
Remittances; renewable energy; CO2 emissions; Asian economies; Driscoll-Kraay	This study aims to examined the relationship between remittances and carbon emissions with moderating role of renewable energy in remittance-receiving selected Asian economies. Annually data taken from World Bank database, used for Bangladesh, Cambodia, India, Indonesia, Kyrgyz Republic, Nepal, Pakistan, Philippines and Sri Lanka for the period 2000-2021. The empirical design includes both country and year fixed effects and Driscoll-Kraay standard errors. However, several key variables were found non-stationary at level using the unit root tests and mixed evidence of panel cointegration, for which reason the final model was estimated in first difference form. The results show a strong negative association between changes in renewable-energy consumption and changes in per-capita CO2 emissions. The interaction remains negative across specifications but becomes statistically weaker after adding FDI and urbanization. The remittance association is statistically insignificant for a low share of renewable energy and negative and becomes statistically significant at a relatively high share of renewable energy. The conclusions offer only partial evidence that a cleaner energy system is associated with lower carbon intensity of economic activities linked to remittance inflows.
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Introduction

For many developing economies, foreign transfers have become a permanent element of foreign finance. Remittances are received mainly through households and are typically spent on current consumption, housing, school, health, and small business, durable goods, and saving. Remittances are significant for the economy, but have an ambiguous environmental impact in these uses. The increased purchasing power within the household may increase demand for electricity, transport services, appliances, construction materials, and other energy related commodities. Meanwhile, better household resources can enable more efficient appliances, better housing, cleaner technologies, education and investments that minimize exposure to traditional fuels (Gillani et al., 2026). The environmental impact of remittance inflows thus also is a function of the technological and energy system in which the remittance income is used.

This is reflected in the empirical literature. Research with various countries, environmental measures, and econometric approaches has found positive, negative, non-linear and context-specific relationships between remittances and environmental pressure. For instance, Ahmad et al. (2022), Khan et al. (2022), Jafri et al. (2022), Shah et al. (2023), Dash et al. (2024), Ali (2026) and Yadou et al. (2024) report environmental impacts of remittance inflows, which vary according to the sample, specification, and measure of environmental quality. However, other studies show that remittances can correlate with reduced emissions or ecological stress, given specific economic and institutional conditions (Zafar et al., 2022; Abdul et al., 2022; Huang et al., 2023; Rahaman & Islam, 2024; Yasin et al., 2024). Recent studies have continued to highlight the divergent nature of remittance impacts, with work from South Asia and elsewhere in the major remittance-receiving economies supporting this view (Qiao et al., 2024; Sadekin, 2025; Ali & Ali, 2025; Hong et al., 2026).

An explanation for these mixed results might relate to the fact that the energy system is typically considered as another determinant of emissions, and not as a factor that alters the environmental impact of remittance-backed activity. This distinction matters. Assume that remittances boost household consumption or investment, and consequently energy demand. If the marginal energy used to meet that demand is predominantly fossil based, the additional activity can be relatively carbon intensive (Ali et al., (2025; Dil & Ali, 2025; Ali & Khan, 2026). For a higher proportion of final energy supplied by renewables, the same amount of gross activity within a household or a business could be correlated with a lower emission pressure. But the main idea of the paper is not that remittances will directly generate renewable energy. Instead, the economic activity enabled by remittance income might have its carbon intensity shifted by the shift in the source of energy.

This is a proposition that is in line with two concerned lines of research. The first is that a growing body of literature has established a connection between remittances and energy consumption, energy access, and the use of renewable energies. For developing countries, Chen et al. (2023) review the remittance-energy nexus, while Karmaker et al. (2023) report evidence on the relationship between remittances and renewable energy use; and Farzana et al. (2023) review remittances, financial deepening, urbanization and renewable energy consumption in Southeast

Asia. The studies by Agradí (2023) and Qamruzzaman (2025) and Khan et al. (2025) give more recent empirical evidence on the link between remittances and the demand for renewable energy and total energy consumption. Second, the emissions impact of economic growth is highly energy-intensity dependent as evidenced by the extensive literature. Overall, recent research in ASEAN and broader Asian samples tends to show that renewable energy use is a significant aspect of decarbonization, albeit with varying magnitudes and relationships between the two across settings (e.g., Kostakis, 2024; Solaymani et al., 2024; Tran et al., 2024; Honma et al., 2025; Gür et al., 2025). Ofori-Sasu et al. (2023) also show how the financial structures can condition the relationship between renewable energy and emissions.

The aim of the present study is to answer a specific question – whether there is any moderating effect by consumption of renewable energy between remittance inflows and CO₂ emissions in selected remittance-receiving Asian economies. This analysis includes the period 2000–2021 for Bangladesh, Cambodia, India, Indonesia, the Kyrgyz Republic, Nepal, Pakistan, the Philippines and Sri Lanka. The countries are selected sample with substantial cross-country variation. They represent a representative subsample that has a wide range of remittance dependence, renewable energy consumption, income, financial development, trade exposure, and emissions.

The paper contributes in three ways. It moves away from the standard remittance–environment relationship towards a conditional relationship where the energy structure can influence the relationship, and it explicitly addresses non-stationarity and mixed cointegration evidence by estimating the main model in first differences; and provides for the use of Driscoll–Kraay inference once heteroskedasticity and cross-sectional dependence are diagnosed. Throughout, the focus is on a clear test of moderation rather than method. The increase of renewable energy consumption is negatively correlated with the reduction of CO₂ per capita emissions. The interaction between remittance and renewable energy is negatively and significantly associated and it does not change significantly when controls are added. There is, however, a trend of increasingly negative remittance association with increasing renewable energy use when using conditional-effect calculations (Ali et al., 2025; Ponduru et al., 2026). The evidence does, however, suggest a moderation interpretation, rather than causal or conclusive.

Literature Review

Remittances and environmental Quality

Theoretically, the environmental impact of remittances is uncertain, as they might finance pollution-reducing or pollution-increasing processes. The first channel is through income and consumption. Remittances create budget slack in households and can help mitigate household spending, especially in the presence of incomplete credit and insurance markets. Previously established household level results indicate that remittances affect the allocation of consumption and investments, such as home ownership, durable goods, education, and productive investments (Adams & Cuecuecha, 2010, 2013; Combes & Ebeke, 2011; Samarasinghe et al., 2020). A more recent study also finds that remittances also have an impact on household consumption and

domestic investment (Salahuddin et al., 2024; Makina, 2024; Ngubane et al., 2025). The changes in the expenditures are significant to the environment because energy and materials are used in constructing houses, in transport, in appliances, in cooling the living environment, and in commercial activity.

The pollution-expanding mechanism is, therefore, simple: remittances increase disposable resources, more spending increases energy demand, and a fossil-fuel based energy system turns some of that energy demand into more pollution. This type of mechanism has been found to be supported in various contexts. Ahmad et al. (2022) find that the relationship between remittance and environment in Pakistan is nonlinear and sensitive to specification. Khan et al. (2022) report that remittances and CO₂ emissions are linked in G20 economies in a dynamic fashion and Jafri et al. (2022) note a critical environmental interaction between remittances and CO₂ emissions within China. Shah et al. (2023) confirm this finding, demonstrating how the environmental effect of remittances varies when financial inclusion and natural resource extraction are taken into account. Remittance and environment relationship is asymmetric, emphasized Dash et al. (2024) in South Asian context as opposed to a fixed effect.

A second channel is in the opposite direction. Remittance can also enhance household income and provide funds for investment in more productive technologies, improved cooking methods, better building materials, education, and upgrading businesses. Remittances can also increase macro-level financial resources or ease liquidity constraints, which can facilitate lower-resource intensive investments. Zafar et al. (2022) demonstrate that remittances are linked with other factors like renewable energy, export diversification, education, and growth in shaping emissions among major remittance recipients. Abdul et al. (2022) include remittances as one of three factors – renewable energy and globalization – among those that explain emissions in China, and Rahaman and Islam (2024) find that remittances are associated with reduced emissions in a larger sample of the world's top remittance receivers. Similarly, Yasin et al. (2024) identify an environmental channel of remittances which is linked to broader macroeconomic factors.

The heterogeneity is confirmed by recent studies based on the ecological footprint and other sustainability indicators. Chishti (2023) maintains that the links are time-varying for Pakistan, Huang et al. (2023) introduce natural resources and finance variables into the remittance equation for South Asia, and Qiao et al. (2024) capture non-linearities in the carbon-intensity effect. There is also further evidence in South Asia from Yadou et al. (2024), Sadekin (2025), Ali and Ali (2025) and Hong et al. (2026). There is no literature available to justify either a positive or a negative hypothesis for the direct remittance coefficient for the universal case. The energy channel is also a blend. Agradi (2023), Chen et al. (2023), and Khan et al. (2025) find that remittances correlate with energy poverty or energy use while Karmaker et al. (2023), Farzana et al. (2023), and Qamruzzaman (2025) find that remittances correlate with renewable-energy consumption. So, the environmental impact of remittance is dependent not only on the amount of energy demand that is changing, but on the source of the energy demand. Accordingly, the first hypothesis is deliberately non-directional:

H1: *Remittance inflows are significantly associated with CO₂ emissions in the selected Asian economies.*

Renewable Energy and CO₂ Emissions

Renewables are expected to lower the carbon intensity of final energy use by replacing or curbing the use of fossil fuels. The magnitude of this effect varies in practice according to the combination of technologies used, the nature of the grid, the nature of the industries and economic development (Yang et al., 2024). Despite this, the recent empirical literature suggests strong evidence of environmental benefits of renewable energy in developing and Asian economies (Yang et al., 2026). When financial openness and economic growth are taken into account, Kostakis (2024) identifies an ecological function for renewable energy in some ASEAN economies.

Moreover, Tran et al. (2024) reveal the pivotal role of renewables in the energy–growth–emissions connection in ASEAN. In this paper, Solaymani et al. (2024) explore the link between renewable energy and financial development in the ASEAN and highlight the importance of financial system integration with decarbonization. A larger sample of Asian economies, covering the entire Asian region, is used by Honma et al. (2025) who find that renewable energy and energy efficiency also play an important role in reducing carbon emissions, with the relative impact varying by economy.

A similar relationship between renewable-energy use and CO₂ emission reduction in ASEAN is presented by Gür et al. (2025). Ofori-Sasu et al. (2023) find that the relationship between renewable energy and emissions in developing countries is affected by the capital market, suggesting that the environmental benefits of renewable energy may vary with the broader economy. Emissions can also be influenced by finance, trade, FDI, and urbanization in terms of production and energy demand (Xie et al., 2026). These macroeconomic conditions have been found to be relevant to environmental outcomes by Shaikh et al. (2026), Sun et al. (2025), (Ali et al., 2026) and Yang et al. (2025). They do not imply a constant effect of control across countries, but justify a parsimonious control set.

The second hypothesis is directional, as the energy mix is relatively directly related to carbon intensity,

H2: *Renewable-energy consumption is negatively associated with CO₂ emissions.*

The Moderating Role of Renewable Energy

The novelty of the present study is that it considers renewable energy consumption as a conditioning variable and not just an independent variable for the emissions prediction. The process could be explained in 4 steps. First, remittances provide a boost to household purchasing power, or investment for the household. Second, there is an increased demand for energy to be

used in housing, appliances, transport, construction, services or small enterprise. Third, the carbon impact of such additional demand is contingent on the energy system providing the demand. Fourth, if the renewable share can be increased the emissions intensity of the additional activity can be lowered. This argument doesn't involve individual remittance-receiving households having to make direct investments in solar panels, wind power, or other renewables equipment. In a few instances, direct household adoption can take place, and new studies on remittances and renewable energy have shown that there is a possibility that such connections exist (Karmaker et al., 2023; Farzana et al., 2023; Qamruzzaman, 2025). But, in general it is a structural one. The emissions from a remittance paid for a normal good or service that is produced in a cleaner energy system should also be lower than the emissions if it is produced in a less clean energy system.

There is some indirect evidence for this conditional view in several recent studies (Nazir et al., 2023). Dilanchiev et al. (2024) explore remittance, FDI, renewable energy and environmental quality for major remittance-receiving countries, highlighting the need to consider these external financial inflows in tandem with energy transition. Abdul et al. (2022) also include remittances in their analysis with renewable energy to account for emissions. Zafar et al. (2022) bring remittances and renewable energy into the same framework of emissions modelling, while Rahaman and Islam (2024) separate the renewable from the non-renewable energy when considering the environmental impacts of remittance inflows.

The present contribution is to shift from the joint inclusion to an explicit interaction test. The sign of the interaction is negative. A negative interaction means that the positive remittance-emissions association will be weaker for high levels of renewable energy. A negative interaction means that the association is already negative and that the association gets more negative as renewable energy use increases. The focus is shifted from the size of the remittance coefficient, which in theory is mixed, to the conditional remittance effect.

H3: *Renewable-energy consumption significantly moderates the association between remittance inflows and CO₂ emissions.*

Data and Methodology

Data and Sample

Data for this study are annual country-level data from the World Development Indicators (2000-2021). The original sample contained 10 countries including Viet Nam, then explain its exclusion because REM is unavailable after 2004. Describe TRD as a baseline control; FDI and URB are the robustness controls. Bangladesh, Cambodia, India, Indonesia, the Kyrgyz Republic, Nepal, Pakistan, Philippines, and Sri Lanka are the part of study sample. The panel is well-balanced in terms of countries but has an unbalanced estimation sample due to the limited number of missing observations in financial development and trade openness. The base-line first difference regression is based on 172 observations over nine countries. CO₂ emissions per capita is the dependent variable, using WDI series and log-naturally transformed.

Personal remittances received as a percentage of GDP are the main explanatory variable. Renewable-energy consumption as a percentage of total final energy consumption is the moderator. The GDP per capita in constant prices is in natural log form. Domestic credit to the private sector as a share of GDP is used for financial development to serve as a proxy, and trade openness as trade in goods and services as a share of GDP is reserved for robustness checks, as is the urban population as a share of total population and FDI net inflows as a share of GDP. Definitions, codes and transformations are provided in Table 1.

Table 1: Variable Measurement

Variable	Measurement	Source
CO ₂	CO ₂ emissions per capita	WDI
REM	Personal remittances received (% of GDP)	WDI
RNE	Renewable energy consumption (% of total final energy consumption)	WDI
GDP	GDP per capita, constant prices	WDI
FD	Domestic credit to private sector (% of GDP)	WDI
TRD	Trade in goods and services (% of GDP)	WDI
FDI	FDI, net inflows (% of GDP)	WDI
URB	Urban population (% of total population)	WDI

Empirical Model

The original moderation design means-centered remittances and consumption of renewable energy. $cREM$ are remittances minus the sample mean of remittances and $cRNE$ are renewable-energy consumption minus the sample mean of renewable-energy consumption. The interaction term $REM_RNE = cREM \times cRNE$. Mean-centering does not change the substantive interaction, but can help the main coefficients be more easily understood around the sample mean of the moderator and will help avoid unnecessary collinearity between the component terms and the product term. Levels of intended use ($cREM$, $cRNE$, interaction of the two, ...) and the log of GDP ($\ln GDP$, FD , TRD), as well as country and year effects were included in the intended levels specification. The time-series characteristics of the panel were not consistent, however, with the assumption that this levels specification was always valid.

The cross-sectionally augmented unit-root approach was applied as it has been found that first-generation unit-root tests are unreliable when the presence of cross-sectional dependence is not taken into account (Pesaran, 2007). The tests reveal the non-stationarity at level but stationarity at first difference for $\ln CO_2$, REM and RNE . $\ln GDP$, FD and TRD have mixed support in CADF/CIPS and supplementary Fisher-ADF tests, but no evidence is found that requires second differencing. The results of the panel cointegration tests are also inconclusive, as only one of the six Pedroni statistics is rejections the null hypothesis of no cointegration at the 5% level, while the other Pedroni statistics are not rejections the null hypothesis, and the Westerlund variance-ratio

test has a p-value of 0.097. The methodological foundations of these panel cointegration checks are from Pedroni (2004) and Westerlund (2005). The primary specification is estimated in first difference form since there is no strong cointegration evidence. This is an intentional conservative option to avoid using potentially false common trends. The estimated equation can be represented as:

$$\Delta \ln CO2_{it} = \beta_1 \Delta REM_{it} + \beta_2 \Delta RNE_{it} + \beta_3 \Delta (REM \times RNE)_{it} + \beta_4 \Delta GDP_{it} + \beta_5 \Delta FDI_{it} + \beta_6 \Delta TRD_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where μ_i denotes country effects and λ_t denotes year effects. The interaction term is the first difference of the original centered $REM \times RNE$ product, rather than a newly constructed product of first differences. An alternative change-by-change interaction is used only as a supplementary robustness check.

Estimator Selection and Diagnostic Strategy

First, a comparison between fixed and random effects was made. The usual Hausman test resulted in a negative chi-square statistic and hence did not meet the conventional asymptotic requirements. Re-estimation, using the sigmamore option, gave very strong rejection of the null (random effects) but also gave a non-positive-definite covariance warning. The paper does not, for that reason, argue for fixed-effects selection to be a mechanical process. Rather, fixed effects are kept in effect, since country-specific factors like migration networks, financial structures, institutions, and the nature of the energy system are likely to be related to the regressors and country effects are correlated with each other and jointly significant. This is a logic that is consistent with Hausman (1978)'s specification testing logic.

The results from the first-difference fixed-effects model were then subjected to the residual diagnostics. The modified Wald test tests for homoskedasticity, while the Wooldridge-type test does not test for first-order serial correlation in the differenced specification. The Pesaran CD test is not able to accept the cross-sectional independence. Drukker (2003) suggests that serial correlation testing is a consistent logic for panel data; and cross-sectional dependence is not a nuisance and should not be ignored, but a substantive characteristic of the data

Inference is done with the heteroskedasticity and cross-sectional dependence corrected Driscoll–Kraay standard errors (Driscoll & Kraay, 1998) in the fixed-effects framework as outlined in Hoechle (2007), and allows for a maximum of one year of lag. The interaction coefficient is not affected by lag-zero and lag-two estimates which are provided only as sensitivity checks.

Robustness and Conditional Interpretation

The first and second difference of FDI and the first difference of urbanization are added as two parsimonious robustness checks. The following variables were not added to the baseline at the same time because there are only nine countries in the sample and the objective is to avoid

overfitting. The most important robustness criterion is that the sign and the magnitude of the interaction is reasonably constant. Substantive interpretation is calculated using conditional linear combinations of the remittance coefficient and the interaction coefficient at 1SD below the mean of consumption of renewable energy, at the mean, and at 1SD above the mean. The value of RNE is approximately 28.16%, 47.39%, and 66.62%, with a mean of 47.39% and a standard deviation of 19.23 percentage points. These calculations are first-differenced, so they should be taken as “conditional short-run association” and not “structural” or “causal” marginal effects.

Empirical Results

Descriptive statistics, correlations, and multicollinearity

The main variables prior to first differencing are summarized in Table 2. The sample is quite heterogeneous. The average of remittance ratio to GDP is 8.68%, ranging from 0.16% to 32.56%, and renewable energy consumption average is 47.39% ranging from 19.8% to 91.3%. This variation can be useful in a moderation analysis because the key variable of interest and the moderator vary within economically meaningful ranges. The sample also exhibits a large variation in terms of financial development and trade openness. Negative observations are FDI, and represent actual net disinvestment or negative net inflows in specific country-years and not a data error.

Table 2: Descriptive Statistics

Variable	N	Mean	SD	Minimum	Maximum
lnCO ₂	198	-0.305	0.756	-2.282	0.850
REM	198	8.680	8.129	0.164	32.564
RNE	198	47.392	19.229	19.800	91.300
lnGDP	198	7.276	0.550	6.305	8.410
FD	187	33.874	18.674	3.829	121.842
TRD	193	62.912	33.413	21.460	146.180
URB	198	35.989	12.997	14.574	66.144
FDI	198	2.218	2.948	-4.855	17.131

Note: REM, RNE, FD, TRD, URB, and FDI are expressed in percentage terms according to their respective WDI definitions. The smaller numbers of observations for FD and TRD reflect missing observations in the original data.

The descriptive correlation presented in Table 3 is high between lnCO₂ and RNE (-0.840) and positive between lnCO₂ and lnGDP (0.625). The correlations between the regressors are relatively small with the highest absolute correlation being between RNE and lnGDP at -0.445.

The maximum VIF is 2.65; the mean VIF is 1.82 and there is no reason to remove baseline variables for multicollinearity.

Table 3: Correlation Matrix and Multicollinearity Diagnostics

Panel A. Pairwise correlations

Variable	lnCO ₂	REM	RNE	lnGDP	FD	TRD
lnCO ₂	1.000					
REM	-0.099	1.000				
RNE	-0.840***	0.069	1.000			
lnGDP	0.625***	-0.250***	-0.445***	1.000		
FD	0.045	0.133*	0.148**	0.230***	1.000	
TRD	0.002	0.267***	0.014	-0.081	-0.105	1.000

Panel B. Variance inflation factors

Regressor	VIF
REM × RNE	2.65
cRNE	1.91
TRD	1.82
lnGDP	1.70
FD	1.63
cREM	1.23
Mean VIF	1.82

*Note: Pairwise observations vary because FD and TRD contain missing observations. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. Pooled OLS was used only to calculate VIF values and was not treated as the main estimator. The VIF results do not indicate problematic multicollinearity*

Model Selection, Diagnostics, and Stationarity

Table 4 presents the model-selection evidence and the model-residual diagnostics. Together, country specific effects are important and substantive considerations suggest that fixed effects are preferred from a financial development, energy mix, and income perspective because these factors might be correlated with remittance dependence. Both the Hausman statistic and the sigmamore version are invalid for this reason because of the covariance problem, and both statistics suggest the use of fixed effects, but with a covariance warning.

The final decision on the estimator to use is then a combination of statistical evidence and the model logic, not an unqualified Hausman decision. The two diagnostics for a first difference specification are critical for the covariance estimator. Groupwise heteroskedasticity exists in the data as indicated by the modified Wald statistic of 174.14, with $p < 0.001$. First-order serial correlation is not detected after differencing, the Wooldridge statistic is 0.028 and the value of p is 0.871. The Pesaran CD statistic, on the other hand, is -2.367 and $p = 0.018$, suggesting cross sectional dependence. Driscoll–Kraay standard errors are consequently used for the final inference.

Table 4: Panel Model Selection and Diagnostic Tests

Panel A. Model-selection evidence

Test / evidence	Statistic	p-value
Country effects jointly equal zero	$F(8,146) = 203.47$	$< .001$
Conventional Hausman test	$\chi^2 = -2.75$	—
Hausman test with sigmamore	$\chi^2(8) = 141.32$	$< .001$
Final panel framework	—	—

Panel B. Diagnostics for final first-difference specification

Test / evidence	Statistic	p-value
Modified Wald test	$\chi^2(9) = 174.14$	$< .001$
Wooldridge serial-correlation test	$F(1,8) = 0.028$	.871
Pesaran CD test	-2.367	.018
Average absolute residual correlation	0.307	—
Final covariance estimator	Driscoll–Kraay, lag 1	—

Note. Because the conventional Hausman procedure produced covariance-matrix problems, fixed effects were retained using both the available statistical evidence and the substantive likelihood that unobserved country-specific characteristics are correlated with the regressors.

The results from the stationarity and cointegration tests are presented in Table 5. $\ln\text{CO}_2$, REM, and RNE are clearly $I(1)$ under the CADF/CIPS tests. The results from the tests of $\ln\text{GDP}$ and FD are inconclusive, as Fisher–ADF supports stationarity after first differencing but CADF (which is somewhat weaker) does not. TRD is also butted with level differencing at level but stationary. It is important to note that the first difference of the original interaction term is stationary at the 5% level. The cointegration results are not robust enough to support a levels relationship: the modified Phillips–Perron statistic from Pedroni does not reject the cointegration hypothesis, the other

Pedroni statistics do not reject the cointegration hypothesis, and the Westerlund variance-ratio test does not reject at a 5% significance level. The main model is thus retained as the first-difference specification.

Table 5: Panel Unit-Root and Cointegration Tests

Panel A. Pesaran CADF/CIPS unit-root results

Variable	Level	p-value	First-difference	p-value	Integration
lnCO ₂	-2.006	.224	-3.635	< .001	I(1)
REM	-2.101	.146	-3.311	< .001	I(1)
RNE	-1.765	.493	-2.891	< .001	I(1)

Panel B. Supplementary Fisher-ADF evidence

Variable	Level	p-value	First-difference	p-value
lnGDP	9.349	.951	46.711	< .001
FD	19.107	.385	35.876	.007
TRD	35.326	.009	83.626	< .001

Panel C. Panel cointegration tests

Test	Statistic	p-value
Pedroni modified Phillips-Perron t	2.497	.006
Pedroni Phillips-Perron t	-0.758	.224
Pedroni augmented Dickey-Fuller t	-1.153	.125
Westerlund variance ratio	1.298	.097

Baseline Estimates and Robustness

Table 6 shows the last Driscoll-Kraay fixed-effects estimates. The coefficient for ΔRNE in the baseline model is -0.0331 and statistically significant at $p < 0.001$. This means that there was a negative conditional association, when annual growth rates of renewable energy consumption and per-capita CO₂ emissions were compared, while the other included annual growth rates and fixed effects were held constant. The outcome is in line with H2. The coefficient on ΔREM is -0.00485 with $p = 0.058$. Since there is an interaction term in the model, this coefficient should not be interpreted as the unconditional remittance effect. It matches the "where" part of the interaction specification. Furthermore, its inference is affected by the Driscoll-Kraay bandwidth, the coefficient remains the same while the p value changes from 0.185 at lag 0 to 0.033 at lag 2.

Therefore the "stand alone" remittance coefficient is not a primary criterion for substantive conclusions. In the baseline model, the central interaction coefficient, $\Delta(\text{REM} \times \text{RNE})$, is equal to -0.000186 and has a p value of 0.050 . The sign agrees with the theoretical prediction that a higher share of renewable energy is related to better remittance–emissions connections. But the statistics are on the edge of being questionable. This note of caution is relevant in the robustness specification. Adding ΔFDI to the interaction does not change the sign, it is still negative at -0.000172 , and the corresponding p-value is now 0.074 . When ΔURB is added, the coefficient is -0.000188 with $p = 0.080$. All three of the interaction estimates are close in size, with the same sign, but none are consistently significant at the 5% level.

The rest of the controls are not statistically significant: ΔFDI has $p = 0.408$ and ΔURB has $p = 0.954$. Their role, however, is to examine whether the main interaction is robust to other macroeconomic controls. If this is the only criterion used, the interaction is economically stable. The within R^2 changes only slightly from 0.7125 in the baseline model to 0.7143 with FDI; it is unchanged with urbanization. The bandwidth sensitivity exercise also helps to estimate the interaction stability. The coefficient doesn't change when Driscoll–Kraay is 0 lag, 1 lag, and 2 lag. The corresponding p-values are 0.038 , 0.050 , and 0.039 . This does not make it strong evidence, but it does indicate that the baseline interaction is not merely a consequence of choosing lag one as this results in the smallest p-value, actually lag one is the most conservative of the three for the interaction.

Table 6: Driscoll–Kraay Fixed-Effects Estimates and Robustness Checks

Variable	Model Baseline	1 Model + FDI	2 Model + Urbanization	3
ΔREM	-0.004849^* (0.002415)	-0.005569^{**} (0.002225)	-0.004900^* (0.002614)	
ΔRNE	-0.033126^{***} (0.002845)	-0.033587^{***} (0.003016)	-0.033140^{***} (0.002780)	
$\Delta(\text{REM} \times \text{RNE})$	-0.000186^{**} (0.000089)	-0.000172^* (0.000091)	-0.000188^* (0.000102)	
$\Delta\ln\text{GDP}$	0.342762 (0.262453)	0.366088 (0.252997)	0.343921 (0.263696)	
ΔFD	0.002169 (0.001590)	0.002141 (0.001643)	0.002159 (0.001603)	
ΔTRD	0.001441 (0.000907)	0.001580 (0.000915)	0.001446 (0.000944)	
ΔFDI	—	-0.001868 (0.002208)	—	
ΔURB	—	—	0.000625 (0.010783)	

*Note: Driscoll–Kraay standard errors are reported in parentheses. * $p < 0.10$, ** $p \leq 0.05$, *** $p < 0.01$. The interaction coefficient remains negative and similar in magnitude across all three specifications, although its statistical significance weakens after adding FDI and urbanization. DK lag-sensitivity checks for the baseline interaction coefficient show that the estimate remained -0.0001857 under lag 0, lag 1, and lag 2, with corresponding p -values of 0.038, 0.050, and 0.039.*

Conditional-Effect Calculations

The conditional remittance association is reported at low, mean and high renewable energy levels in Table 7. The estimated effect is -0.00128 with $p = 0.647$, and is not statistically different from zero at low RNE share levels (around 28.16%). The estimate then changes to the more negative value of -0.00485 at the sample mean of 47.39% with marginal probability of $p = 0.058$. With a relatively high percentage of renewable energy of 66.62%, the estimate is found to be -0.00842 with $p = 0.015$ and the 95% confidence interval is completely below zero.

Table 7: Marginal Effect of Remittances at Different Levels of Renewable Energy

Renewable-energy condition	RNE level (%)	Marginal effect of Δ REM	DK SE	t statistic	p-value
Low RNE: Mean - 1 SD	28.16	-0.001278	0.002752	-0.46	.647
Mean RNE	47.39	-0.004849	0.002415	-2.01	.058
High RNE: Mean + 1 SD	66.62	-0.008420	0.003158	-2.67	.015

Note: RNE has a sample mean of 47.39% and standard deviation of 19.23 percentage points. At low renewable-energy consumption, the estimated remittance association is statistically indistinguishable from zero. The association becomes increasingly negative as renewable-energy consumption rises and is statistically significant at the high-RNE level. Because the estimates are observational, they should be described as conditional associations rather than causal effects.

Overall, the association between remittance and renewable-energy use increases in a negative direction, as indicated by the negative gradient of the pattern, which is consistent with the moderation argument. The final regression has been calculated using first differences and the interaction term is the first difference of the centered product term so do not interpret the interaction as a structural causal derivative. The best approach is to use them as a guide to understanding the direction and economic trend of the estimated interaction. The hypothesis assessment is a purposeful cautious statement. H1 is given a limited grade of evidence, since the remittance coefficient around the reference condition is only a marginal one in the baseline model, and is not the unconditional effect when the interaction is added. In the final specification, H2 is strongly supported due to the negative value of Δ RNE and the value of Δ RNE is well determined throughout. The Conditional Pattern is consistent with the hypothesized mechanism and the interaction is negative and highly stable in magnitude, but the interaction is not

significant at the conventional 5% level after the additional controls are added to the model for H3.

Discussion

The key result is that remittances do not automatically have a negative or positive environmental impact. Instead, the environment related to remittance-financed economic activity seems to be more or less dependent on the environment of the surrounding energy structure. This interpretation is useful to harmonies an empirical literature that links remittances with both increased and decreased environmental pressures. The emission effects of remittances that relieve household budget constraints and boost consumption, construction, transport or small-scale investment, depend on the energy used. More economic activity can come with less carbon burden in a system that uses more renewable energy as opposed to a system that relies more heavily on fossil fuels.

This negative sign for ΔRNE is in line with the recent Asian evidence that highlights the decarbonization contribution of renewables. Renewable energy is also found to be relevant to better environmental performance in samples from ASEAN or wider in Asia by Kostakis (2024), Tran et al. (2024), Honma et al. (2025), and Gür et al. (2025). The other studies cited, such as Solaymani et al. (2024) and Ofori-Sasu et al. (2023), further indicate that the financial and economic environment is also relevant, and that the relationship between renewable energy and emissions can be moderated by financial-market development. The present results bring another conditioning mechanism on board – external household income in the form of remittances.

The interaction result is also in keeping with the growing evidence of the relationship between remittances and energy consumption. Karmaker et al. (2023) and Farzana et al. (2023) link remittance flows with use of renewable energy, while Qamruzzaman (2025) shows a positive relationship between remittance and renewable energy use in BIMSTEC economies. The relevance of remittances for energy consumption and energy access in general is demonstrated by Chen et al. (2023), Agradi (2023), and Khan et al. (2025). The findings of these studies suggest that remittance income may have an effect on the energy demand. The present paper attempts to answer the complementary question of whether the type of energy use alters the emissions linkage of that remittance-related use.

The results should, however, be interpreted with caution. The interaction with the baseline is only significant at the 10% level with FDI or urbanization. The evidence thus does not support an argument that renewable energy universally or strongly dampens the relationship between remittance and emissions. The consistency of the sign and magnitude of the coefficient is more convincing. The coefficient of the interaction term is the same in the three specifications of the baseline, FDI, and urbanization, while the coefficient of the interaction term is the same under the three different lags of Driscoll-Kraay. The distance pattern indicates that the direction estimated is not being controlled or covaried by one of the settings, although the estimates are only

statistically precise because of the small sample of cross countries. The conditional-effect calculations are useful for an economic interpretation. The remittance association is roughly zero and imprecise at low renewable energy consumption. The higher the rate of renewable energy use, the more negative it is, and it is different from zero at one standard deviation above the mean. This pattern is consistent with the notion that a less carbon-intensive energy mix will lead to lower carbon intensity of new economic activity. It also provides a rationale for the divergent results found in country-based studies on remittances. Average remittance coefficients can include very different underlying circumstances as countries vary significantly in their characteristics of renewable-energy penetration, energy access, industrial structure, and financial systems (Zhang et al., 2026).

The results also shed light on the general discussion on financial development, trade, FDI and urbanization (Nazir et al., 2026). The latter are potential remittance-renewable interaction carriers in the emissions literature (Dong et al., 2024; Quy et al., 2024; Shaikh et al., 2026) but do not measurably affect the interaction between remittance and renewable in this sample. That doesn't imply they are not significant to the environment. Instead, in the specification employed in this short-run first difference model, their extra explanatory power is not exactly measured after the incorporation of country and year effects and the core variables. The analysis also reveals the importance of the properties of time series. However, there was a different pattern of significance within a model of fixed-effects and some variables were not stationary, and the results of the cointegration tests were mixed. The first-difference method gives up the interpretation of the long run but gives a more conservative basis for the short-run association and does not choose a specification because it yields greater significance.

Conclusion and Policy Implications

This study analyzed how the relationship between remittances and CO₂ emissions is influenced by renewable energy consumption in the period 2000-2021 in 9 selected Asian economies. The analysis was driven by a simple mechanism: remittances can contribute to an increase in household consumption and investment spending, which can increase energy demand; and the carbon intensity of energy demand is partly determined by the energy mix. Thus, the empirical approach was directed towards the relationship between remittance and renewable energy rather than just considering the two as separate factors affecting emissions.

The final model was estimated in first differences as the panel unit-root tests showed that some of the key series were non-stationary and the results of the panel cointegration tests were mixed rather than strong evidence of a stable-level relationship. Standard errors were, respectively, robust to the presence of heteroskedasticity and of cross-sectional dependence in the final model, which warranted the use of country and year fixed effects, and also the use of Driscoll-Kraay standard errors. The design is intentionally understated for two reasons: a) it does not assert causal identification and b) it does not resort to increasingly complex estimators simply to obtain significance.

Three empirical conclusions results are, Firstly, growth in renewables is strongly and inversely related to per-capita CO₂ emissions. Second, the remittance–renewable–energy relationship is negative and quite robust, with respect to both the baseline and additional–control specifications. Third, the evidence of this interaction is, at best, highly suggestive, not definitive. Specifying FDI and urbanization requires the p-value to drift towards 10%, while the conventional level is at 5%. Conditional-effect calculations show that while the relationship between remittance and renewable energy varies, there is a well-defined trend toward a more negative remittance association as the proportion of renewables increases, and statistical significance is detected at a relatively high level of renewables consumption.

The policy implication is not to try to decrease or re-direct remittances for environmental reasons. Remittances are private household resources that are used for welfare, resilience and development purposes and that go far beyond environmental policy. The more applicable one is that the increased purchasing power of households can have less impact on the environment if the energy system surrounding them is cleaner. Reliable, renewable electric power, smart grid technologies, cost reductions for clean household technologies, and access to energy-efficient appliances and equipment can enable households to use the income increase to better meet their needs while reducing their carbon footprints.

This process can be supplemented by financial institutions and remittance–service–providers without assuming that remittances should be regulated. Financial products that encourage voluntary investments in green products, financing with lower costs for rooftop solar or efficient appliances, and information programs that are tied to formal remittance channels may be effective in lowering barriers to clean household investment. Although the evidence of Karmaker et al. (2023), Farzana et al. (2023), and Qamruzzaman (2025) indicates that remittance flows could be linked to the adoption of renewables, the programs need to be built around household choice and not compulsory earmarking.

A second policy implication is with regards to energy planning. There are countries that have remittance inflows that can lead to more consumption growth than what conventional industrial policy can explain. The environmental consequences of remittance–financed welfare gains are likely to be less positive if people are more likely to save when their income rises and consumption of electricity and transport is fossil-based. Energy efficiency and clean transport can thus play a role in meeting both climate policy and household development goals, especially with a view to expanding the supply of renewables. From the interaction that took place in this paper, it has been indicated that these two policy areas should not be considered as isolated from each other. Lastly, the lack of statistical strength of the interaction in the robustness models is policy relevant. There is inadequate evidence to support a narrow policy based on the estimated coefficient. The moderation result is not a policy justification for expanding renewable energy, it has an independent environmental justification. The key contribution of the study is to demonstrate that the energy context should be included in the remittance–environment discussion.

Limitations and Future Research

The study has a number of limitations. First, the final sample is limited to nine countries, and Viet Nam is no exception, as the principal WDI remittance series ends in 2004. The results are thus not generalizable to Asia as a whole, but to the selected economies. Secondly, national level data on remittances do not provide information on the nature of use of remittances by households. To be able to test the proposed mechanism more directly, a household-level dataset that correlates the receipt of remittances, ownership of various appliances, transportation, housing investments, and energy source would be useful. Third, using renewable energy is a broad indicator of renewable energy use, and does not indicate which fuel source provides the marginal electricity service that meets the additional demand. Fourth, the first difference specification focuses on annual changes in the short run. It is a conservative reaction to the evidence of unit roots and cointegration, but does not reveal a structural equilibrium in the long run. Fifthly, the research type is associational. No causal identification method or instrument or natural experiment is used in order to eliminate important sources of confounding, but this is because of country and year effects only.

Future studies might incorporate exogenous migration and/or remittance shocks, account for the distinction between formal and informal remittance channels and analyze the potential pathways through which the interaction operates, such as electricity-sector decarbonization, clean cooking, or distributed renewable technologies. Extended and more area-wide panels would also enhance statistical power.

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