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KEYWORDS	ABSTRACT
Natural-resource rents; Renewable energy; CO ₂ emissions; Resource-intensive economies; Driscoll-Kraay; CS-ARDL	Are the adversative environmental impacts of natural-resource reliance being reduced by renewable energy? The present study investigates the linkage among natural-resource rents, renewable-energy, and CO ₂ emissions in the nine resource-intensive Asian economies in the period 1995–2022. The analysis uses balanced panel data, and fixed effects with Driscoll–Kraay standard errors as the main estimator and CS-ARDL as a robustness framework are employed. The outcomes show that the relation between renewable-energy and CO ₂ emissions is still strong. In contrast, emissions are not significantly influenced by natural-resource rents directly. More crucially, natural resource rent–renewable energy interaction is statistically unimportant, which suggests that there is no strong evidence that renewable energy declines the natural resource rent–emissions relationship. The CS-ARDL results support an adjustment process; the long-run coefficients are not statistically significant. Overall, the outcomes indicate that renewable energy makes a direct contribution to the reduction of emissions, and that there is still a need for larger structural transformation to achieve a separation between the resources and their impact on the environment.
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Introduction

The shift of Asian economies to resource-rich ones is a challenging one. National income, industrial development, and export revenues rely on natural resources, but a growth model that derives national wealth from natural resources can create an increasing reliance on fossil fuels and a growing burden on the environment. Meanwhile, renewable energy is also growing as a viable pathway to decarbonizing development. In recent years, the ecological impacts of natural-resource rents are quite non-uniform; some research has linked natural-resource rents to greater carbon emissions, whereas others have linked them to income, technology, institutions, or the composition of resources (Nazir et al., 2026; Sharif et al., 2026; Yang et al., 2025).

This relationship can be further complicated by renewable energy. There is increasing evidence that renewable energy use is correlated with reduced emissions, especially when it replaces activities with high levels of fossil fuel consumption. Lin et al. (2024) found that a large share of renewable energy in energy usage decreases per capita CO₂ emissions, and Ben Mbarek (2026) found that a rise in the share of RE contributes to improving environmental quality in the energy sector of the GCC economies. But the impact of renewables is limited in countries with a continued high fossil fuel share of energy supply, as observed in selected countries in the same group in the recent past (Jiang et al., 2026; Zhang et al., 2026). The differing results show that the ecological impact of renewables is sensitive to economic and resource conditions.

Renewable energy can have a greater influence than on emissions itself. It could also influence the environmental impacts of resource dependence. Q. Wang et al. (2024) find, using data for 130 countries, that the carbon-reducing impact of renewables varies with natural resource rents. The impacts of resource rents and renewable energy are also found to differ in various economic-growth regimes in recent nonlinear evidence from G7 economies (Esmailpour Moghadam et al., 2026). This poses an interesting question for resource-constrained Asian economies: does renewable energy reduce the natural-resource dependency-CO₂ emission relationship?

Though there is growing literature, there are still a lot of gaps. Much of the existing literature is based on a global sample, or some other collection of countries, with only a handful of studies focusing specifically on the link between total natural-resource rents and renewable-energy consumption in a specifically targeted sample of resource-intensive Asian economies. Furthermore, cross-sectional dependence and non-uniform responses to a wide range of shocks have been shown to be present in the data by recent studies, and hence, traditional panel estimators are not appropriate for this analysis (Anas et al., 2025; Shuayb et al., 2025).

To fill these gaps, the current paper investigates the nine economies in Asia that are also resource-intensive, from 1995 to 2022. It gives 3 contributions. Firstly, it jointly assesses natural-resource rents, renewable energy consumption, and CO₂ emissions in the economies in which resource dependence is still economically significant. Second, it directly examines the moderating effect of renewable energy by observing directly at an interaction between natural-resource rents and renewable-energy consumption. Third, it uses an estimation approach that explicitly recognizes heteroskedasticity, serial correlation, cross-sectional dependence, and slope heterogeneity. The

study thus not only demonstrates the potential emission reductions of renewables but also their potential to alter the environmental impacts of resource dependency.

Literature Review

Natural-Resource Rents and Environmental Degradation

The theory of the association between NRRs and environmental degradation is unclear. More oil, gas, mineral, and other resource extraction can lead to increased emissions because of more energy consumption in extraction, processing, transport, and increased industrial development (Shafiq et al., 2021). Resource dependence may also hinder structural shift to cleaner industries. New data backs up this worry. In contrast, both Lin et al. (2024) and Soni and Manogna (2025) show that in both developed and developing economies, natural-resource rents have positive effects on per capita emissions. A similar finding was obtained by Ben Mbarek (2026) who noted that natural-resource rents increase emissions in GCC economies. But not all the relationship is universal. In a study of 32 Asian economies, Imran et al. (2025) find that, under certain circumstances, total natural-resource rents can lower GHG emissions. Contrary to this, previous Asian data indicate that the environmental impact varies between income levels and resource-exporting economies (Luo et al., 2023; Nazir et al., 2023; Sui et al., 2026). This inconclusive result leaves room for doubts that natural-resource rents uniformly affect the environment across countries. Therefore, this study is based on a non-directional hypothesis:

H1: Natural resource rents are negatively linked with environmental degradation.

Renewable Energy and Environmental Degradation

Reducing emissions through the usage of renewable energy is predictable to come from dropping dependance on carbon-intensive energy bases and diminishing the fossil fuel input in production. This channel has been strongly supported by recent empirical evidence (Yang et al., 2026; Yang et al., 2024). The renewable-energy share is originated to decrease CO₂ emissions by Lin et al. (2024), and Işık et al. (2024) report a negative link between RE uses and emissions in OECD economies. Renewable energy helps to enhance eco-friendly sustainability in resource-rich countries, the same as Shuayb et al. (2025) state. But the latest Asian evidence indicates that this relationship is contingent upon the structure of the energy system. Adoption of renewable energy does not have significant effects on emissions at the various quantiles in selected SCO countries; according to Anas et al. (2025) this could signify ongoing reliance on fossil fuels. Ben Mbarek (2026) finds, however, that there is a significant emissions-reducing role for the GCC economies. These distinctions underline the need to consider the resource-intensive Asian economies separately. Thus, the second hypothesis is:

H2: Renewable energy consumption is negative associated with environmental degradation.

Moderating Effect of Renewable Energy

The environmental impact of natural-resource rents could be reliant on the energy transition and the natural-resource income interaction. In fossil-fuel-intensive economies, increases in resource

rents can lead to increased carbon-intensive production. But with the significant rise in the importance of renewable energy, a portion of the energy demand of economic and industrial activity can be met using more environmentally friendly sources, thus reducing the emissions impact of resource dependence. There is recent empirical research to consider this relationship not a simple linear relation, but a conditional one. Q. Wang et al. (2024) demonstrate that the carbon-reduction impact of renewable energy varies according to the natural-resource rents level in 130 countries. Similarly, Esmailpour Moghadam et al. (2026) show that natural-resource rents and renewable energy can have a regime-dependent influence on CO₂ emissions. The studies suggest that resource dependence and renewable energy need not be considered as separate environmental factors. Still, there is a scarcity of observed evidence for how renewable energy affects the NRR-CO₂ nexus in resource-intensive Asian economies. The present study thus explicitly tests the interaction:

H3: *Renewable energy moderates the relationship between natural-resource rents and CO₂ emissions*

Economic Growth, Industrialization, and CO₂ Emissions

The rise of economic activity with the rise of income can lead to an increase in environmental pressure if this translates into higher energy demand, transport, and industrial production, and fossil-fuel use continues to rise. This mechanism is supported by recent evidence in the region (F. Wang et al., 2024). As observed by X. Wang et al. (2025) in four world regions, economic growth and industrialization typically lead to rising CO₂ emissions, but with varying magnitudes depending on the region (Xie et al., 2026). More recently, the close links between industrial development, electricity consumption, and carbon emissions in Asia have also been highlighted (Ali et al., 2026). Economies that are more resource-heavy could be especially vulnerable, as economic growth in these economies is frequently connected to the extraction, processing, construction, manufacturing, and development of energy-intensive infrastructure. These considerations lead to the following hypotheses:

H4: *Industrialization are positively related with CO₂ emissions.*

H5: *GDP per capita is positively related with CO₂ emissions.*

Research Gap

Recent studies in the literature have shown that there is a link among natural resources, renewable energy, economic growth, and environmental outcomes, and the evidence is mixed. There is growing evidence that the effect of resource rents is regionally and developmentally different and that the environmental benefit of renewables is related to the energy infrastructure. More importantly, there has been less attention to the direct effect of renewable energy on the strength of the resource rent-emissions relationship in resource-intensive Asian economies. This paper offers a specific test of this unstudied relationship by using panel methods that are robust to common shocks and country heteroscedasticity.

Data and Methods

Data and Sample

The aim of the present research is to explore the environmental considerations of natural-resource dependence and renewable-energy use in nine economies in the resource-rich Asian region: Saudi Arabia, the United Arab Emirates, Kazakhstan, Iran, Indonesia, Malaysia, Mongolia, Vietnam, and the Kyrgyz Republic. The sample is balanced and includes the 1995-2022 time period. The purpose of the selection of these economies is that natural-resource-based activities are still economically significant, but energy structure and development vary widely. Finally, this combination is useful for investigating whether there is an association between renewable energy and a shift in the relationship between natural-resource rents and environmental pressure. Annual data were obtained from the WDI database (World Bank, 2026).

Measurement of Variables

CO₂ emissions per capita (CO₂) is the dependent variable and is expressed as carbon dioxide emissions excluding land use, land use change, and forestry in tonnes of CO₂ equivalent per capita. The variable is then converted to its natural log (lnCO₂) for estimation. Total natural-resource rents (NRR, percent of GDP) is the main explanatory variable. This is the total amount of rents collected from oil, natural gas, coal, minerals, and forests. Renewable-energy consumption is calculated as the proportion of renewable energy in total final energy consumption (RNE). The main control variables used include GDP per capita and industrialization. GDP per capita (GDP) is converted to constant 2015 US dollars and natural log transformed (lnGDP). Industrialization (IND) is the value added of industry (including construction) as a share of GDP. Trade openness and urbanization are considered as robustness factors and are not included in the main specification. Trade openness (TRD) is defined as the sum of exports and imports of goods and services divided by GDP, while urbanization (URB) is the number of people living in towns and cities divided by the total number of people.

Table 1: Variable Descriptions

Abbreviation	Variables	Unit
lnCO ₂	CO ₂ emissions	Natural log of t CO ₂ per capita
NRR	Natural-resource rents	% of GDP
RNE	Renewable-energy consumption	% of total final energy consumption
lnGDP	GDP per capita	Natural log of constant 2015 US\$
IND	Industrialization	Industry value added, % of GDP
URB	Urbanization	Urban population, % of total population
TRD	Trade openness	Trade, % of GDP

Data source: All variable data are taken from the WDI database.

Model Specification

The study focuses on whether renewable-energy moderates the association between natural-resource rents and environmental degradation (CO₂). To test this possibility, NRR and RNE are mean-centered before constructing their interaction term. The baseline model is written as:

$$\ln(\text{CO}_{2,it}) = \beta_0 + \beta_1 \text{NRR}_{it}^c + \beta_2 \text{RNE}_{it}^c + \beta_3 (\text{NRR}_{it}^c \times \text{RNE}_{it}^c) + \beta_4 \ln(\text{GDP}_{it}) + \beta_5 \text{IND}_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

NRR^c and RNE^c are the mean-centered natural-resource rents and renewable-energy use, respectively; the *i* is the country index, the *t* is the year index; μ_i is the country-specific fixed effects; λ_t is the year fixed effects; and ε_{it} is the error term. The interpretation of the interaction coefficient is done with caution. If there is a significant interaction, it means that the relationship among natural-resource rents and CO₂ emissions is diverse depending on renewable-energy use. If the coefficient is not significant, there is not enough evidence of the moderation occurring.

Econometric Strategy

The analysis starts with descriptive statistics, pairwise correlations, and variance inflation factors to investigate basic characteristics of the data and possible multicollinearity. A fixed effects model with year effects is then estimated, with the intent of controlling for any common time-specific influences and country characteristics that are fixed over time. Multiple panel diagnostics are performed prior to choosing the final estimator. The modified Wald test is used to test for Groupwise heteroskedasticity, and Drucker (2003)'s Wooldridge-type panel autocorrelation test is used for serial correlation.

To examine the cross-sectional dependence, Pesaran's CD approach is used, since economic and energy shocks may not be country-specific but can spread among the economies Pesaran (2007). The cross-sectional dependence makes stationarity testing challenging, and Pesaran's cross-sectionally augmented panel unit-root procedure is used to test stationarity. The CADF/CIPS test is an extension of the traditional unit root tests that incorporates the cross-section averages, thus enabling the test to be used with common shocks that affect the components of the panel (Pesaran, 2007). The Pesaran and Yamagata (2008) test is also used to check for slope homogeneity. The Driscoll–Kraay standard errors are used with the fixed-effects estimator as the primary estimator. Driscoll–Kraay covariance estimates are fairly insensitive to general types of heteroskedasticity, temporal dependence, and cross-sectional dependence and are suitable for the present panel, for which diagnostic evidence suggests they exist Driscoll and Kraay (1998).

The cross-section augmented autoregressive distributed lag (CS-ARDL) specification is an additional robustness exercise estimated. This framework enables dynamic responses and allows the unobserved common factors to be controlled for using cross-sectional averages, as described by Chudik and Pesaran (2015). The Driscoll–Kraay specification continues to be the most important model as it tests the key hypotheses of the study directly and economically. CS-ARDL is not the main estimator, but rather is used as a supplement to the robustness assessment.

Empirical Results

Descriptive Statistics and Correlation Analysis

The descriptive statistics for the variables analyzed are shown in Table 1. The average natural resource rent is 16.07% of GDP, and the average of $\ln\text{CO}_2$ is 1.687. On average, renewable energy constitutes 12.79% of total final energy consumption, but the relatively high standard deviation of 17.01% suggests that there is a wide range of renewable energy use across countries and years. Industrial value added is an average of 39.21% of GDP, and the average trade openness and urbanization are 99.97% and 59.38%, respectively.

Table 2: Descriptive Statistics

Variable	N	M	Median	SD	Min	Max	Skewness	Kurtosis
$\ln\text{CO}_2$	252	1.687	1.895	1.066	-0.740	3.459	-0.227	1.931
NRR	252	16.072	12.671	11.574	0.656	55.024	0.953	3.446
RNE	252	12.785	3.000	17.007	0.000	64.900	1.214	3.248
$\ln\text{GDP}$	252	8.575	8.395	1.218	6.376	11.041	0.360	2.247
IND	252	39.209	38.963	9.794	16.682	66.429	0.040	2.904
URB	252	59.379	60.955	18.317	21.454	85.515	-0.345	1.924
TRD	252	99.968	94.686	45.013	29.228	220.407	0.550	2.553

Note. $\ln\text{CO}_2$ = natural logarithm of CO_2 emissions per capita; NRR = natural-resource rents; RNE = renewable-energy consumption; $\ln\text{GDP}$ = natural logarithm of GDP per capita; IND = industrialization; URB = urbanization; TRD = trade openness.

Table 3 shows a number of interesting relationships between the variables. Natural-resource rents, GDP per capita, industrialization, and urbanization are positively correlated with CO_2 emissions, and consumption of renewable energy is strongly negatively correlated with CO_2 emissions. Natural-resource rents and GDP per capita are also negatively correlated with renewable energy. There are certain correlations between explanatory variables which are relatively high, especially the correlation between the two variables of renewable energy and GDP per capita and between urbanization and GDP per capita. As a result, urbanization is not included in the main specification but only forms a robustness control.

Table 3: Correlations

Variable	1	2	3	4	5	6	7
1. $\ln\text{CO}_2$	1.000						
2. NRR	.662***	1.000					
3. RNE	-.879***	-.568***	1.000				
4. $\ln\text{GDP}$	.924***	.574***	-.680***	1.000			
5. IND	.574***	.644***	-.304***	.732***	1.000		
6. URB	.900***	.640***	-.845***	.854***	.612***	1.000	
7. TRD	.033	-.213***	-.035	.085	-.014	-.041	1.000

Note. N = 252. *** p < .001.

The variance inflation factor results in Table 4 are for further inspection of multicollinearity. In the final baseline specification, VIF values range from 3.88 for industrialization to 9.02 for renewable energy, with a mean VIF of 5.87. These values fall within the moderate range of multicollinearity and are less than 10, which is considered a threshold. Therefore, the core variables are retained in the main model.

Table 4: Variance Inflation Factors

Predictor	VIF	Tolerance
RNE	9.02	.111
NRR	6.67	.150
NRR×RNE	5.14	.194
lnGDP	4.63	.216
IND	3.88	.258
Mean VIF	5.87	—

Panel Diagnostic Tests

The main regression was estimated after several diagnostic tests were performed to check for potential problems in the panel data presented in Table 5. The modified Wald test strongly rejects the null hypothesis of homoskedasticity with $\chi^2(9) = 313.17$ and $p < .001$. This indicates that there is groupwise heteroskedasticity. Also, the Wooldridge test for first-order serial correlation is rejected: $F(1, 8) = 366.24$, $p < .001$.

Further, the Pesaran cross-sectional dependence test gives a CD statistic of -3.583 at $p = .0003$, thus suggesting significant dependence across the sampled economies. This is a plausible result since several Asian countries could be subject to energy price, commodity market, regional economic, and global shocks at the same time. The uniformity of slope homogeneity is also rejected. The Pesaran-Yamada test shows Delta of 9.785 is significant at $p < .001$ and adjusted Delta of 11.299 significant at $p < .001$. So, it can be expected that the influence of the explanatory variables may differ from one country to another within the nine countries. Combined, these diagnostics substantiate the use of estimators which are able to account for heteroskedasticity, serial correlation, cross-sectional dependence, and heterogeneous panel behavior.

Table 5: Panel Diagnostic Tests

Diagnostic	Statistic	p
Modified Wald heteroskedasticity	$\chi^2(9) = 313.17$	< .001
Wooldridge autocorrelation	$F(1, 8) = 366.24$	< .001
Pesaran cross-sectional dependence	$CD = -3.583$	.0003
Pesaran-Yamagata Δ	9.785	< .001
Adjusted Δ	11.299	< .001

Note. The diagnostic results justify an estimator robust to heteroskedasticity, serial correlation, and cross-sectional dependence.

Panel Unit-Root Results

Since cross-sectional dependence exists, the stationarity properties of the variables are explored with the help of the second-generation Pesaran CADF/CIPS procedure. In the results reported in Table 6, the consumption of renewable energy is stationary at level with $p = .001$; thus, it is considered $I(0)$. In contrast, none of the following variables, in levels, reject the unit-root null at the 5% level: $\ln\text{CO}_2$, natural-resource rents, $\ln\text{GDP}$, industrialization, or trade openness. The stationary properties of all these variables are obtained after first differencing, and the results are significant at the 1% level ($p < .001$), so they are assumed to be $I(1)$. Industrialization is significantly different from $I(0)$ at the 10% level, but not at the conventional 5% level, so it is conservatively identified as $I(1)$. Important: None of the variables are of order 2. We can use the CS-ARDL model as another dynamic robustness specification, because of the mixture of $I(0)$ and $I(1)$ variables.

Table 6: Pesaran CADF/CIPS Panel Unit-Root Results

Variable	Level	p	First-difference	p	Order
$\ln\text{CO}_2$	-1.406	.863	-4.019	< .001	$I(1)$
NRR	-1.525	.766	-3.704	< .001	$I(1)$
RNE	-2.751	.001	-3.647	< .001	$I(0)$
$\ln\text{GDP}$	-1.573	.719	-3.151	< .001	$I(1)$
IND	-2.220	.077	-3.361	< .001	$I(1)$
TRD	-1.361	.891	-3.642	< .001	$I(1)$

Note. One lag and a constant were used. IND rejects the unit-root null at the 10% level but not at 5%; it is conservatively treated as $I(1)$. No variable is $I(2)$.

Main Driscoll-Kraay Fixed-Effects Results

The main fixed-effects estimates with Driscoll-Kraay standard errors are reported in Table 7. The model is jointly significant, $F(32, 27) = 508.19$, $p < .001$, and the within R^2 is 0.8507. Throughout the estimation, country and year fixed effects are considered. The coefficient of natural-resource rents is very small ($-\$0.0001$), with a p -value of .968, indicating that the impact is not statistically significant. This finding offers no evidence that fluctuations in natural-resource rents, in isolation, can be systematically linked to CO_2 emissions, after accounting for the other variables that appear in the model. The coefficient of the use of renewable energy is negative and highly significant ($\beta = -0.0193$, $p < .001$). With other factors remaining the same, a one-percentage-point increase in renewable energy corresponds to an approximately 1.9% decrease in CO_2 emissions, which are expressed in logarithmic form. This is the best and most stable environmental outcome among the baseline models.

Natural-resource rents and renewable energy are positively correlated, although the correlation is not significant ($\beta = 0.000154$; $p = .351$). The results therefore cannot be used as a justification

that the use of renewables has a significant impact on the relationship between natural-resource rents and CO₂ emissions. The main specification thus does not support the proposed moderation effect. GDP per capita has a positive and statistically significant coefficient ($\beta = 0.4518$, $p < .001$). Since the coefficient is expressed in logarithmic form for both GDP per capita and CO₂ emissions, it may be interpreted as an elasticity. Other factors being equal, a 1% rise in income per capita correlates with a 0.45% rise in CO₂ emissions. Emissions also positively and significantly correlate with industrialization ($\beta = 0.0060$, $p = .002$). There is a roughly 0.6% increase in CO₂ emissions for each percentage point rise in the share of GDP from industry. This finding indicates that industrial growth continues to be a key cause of environmental stress in the selected economies.

Table 7: Driscoll–Kraay Fixed-Effects Results

Predictor	B	SE	t	p	95% CI
cNRR	-0.0001	0.0028	-0.04	.968	[-0.0058, 0.0056]
cRNE	-0.0193	0.0018	-10.46	< .001	[-0.0231, -0.0155]
NRR×RNE	0.0002	0.0002	0.95	.351	[-0.0002, 0.0005]
lnGDP	0.4518	0.0322	14.04	< .001	[0.3858, 0.5178]
IND	0.0060	0.0018	3.36	.002	[0.0023, 0.0097]

Note. $N = 252$; countries = 9; within $R^2 = .8507$; $F(32, 27) = 508.19$, $p < .001$. Country and year fixed effects are included. Driscoll–Kraay maximum lag = 1.

Robustness Analysis

Two alternate Driscoll–Kraay specifications are estimated to assess the sensitivity of the key results to the addition of further controls. The first includes the measure of trade openness. Renewable energy is still negative and highly significant ($\beta = -0.0180$, $p < .001$), and GDP per capita and industrialization are still positively significant. Trade openness is at most weakly significant at the 10% level ($\beta = 0.0008$, $p = .075$). The interaction between natural-resource rents and renewable energy is very weak ($p = .436$), as shown in Table 8. The second robustness model incorporates the concept of urbanization instead of trade openness. Renewable energy continues to have a significant and negative relationship ($\beta = -0.0173$, $p < .001$), while GDP per capita and industrialization continue to have positive significant relationships. The difference in urbanization is not significant at the 5% level ($p = .101$). The interaction term is borderline significant at the 10% level ($p = .074$), but this is not replicated in either the baseline specification or the trade-control specification. This does not give strong evidence for a moderation effect.

Table 8: Driscoll–Kraay Robustness Specifications

Predictor	Baseline	+ Trade	+ Urbanization
cNRR	-0.0001 (.968)	-0.0008 (.758)	0.0003 (.898)
cRNE	-0.0193 (< .001)	-0.0180 (< .001)	-0.0173 (< .001)
NRR × RNE	0.0002 (.351)	0.0001 (.436)	0.0003 (.074)
lnGDP	0.4518 (< .001)	0.4976 (< .001)	0.4432 (< .001)

IND	0.0060 (.002)	0.0047 (.039)	0.0079 (.005)
TRD	—	0.0008 (.075)	—
URB	—	—	0.0095 (.101)
Within R ²	.8507	.8528	.8563

Note. Entries are coefficients with p values in parentheses.

A CS-ARDL model is also estimated to explore the dynamic short-and long-run relationships, taking into account the cross-sectional dependence and slope heterogeneity, and results are summarized in Table 9. The error-correction coefficient is negative and strongly significant ($\beta = -1.055$ at $p < .001$), which suggests that the variables move towards the long-run equilibrium after the short-run disturbances. It is slightly less than -1 , so a bit of overshooting may be required to make adjustment. The short-run and the long-run coefficients of natural-resource rents, renewable energy, natural-resource rent-renewable energy interaction, GDP per capita, and industrialization are statistically insignificant in the CS-ARDL specification. Most importantly, the $NRR \times RNE$ interaction is negligible in both short-run and long-run situations. The post-estimation cross-sectional dependence test shows a CD of -0.232 and a p-value of $.817$, indicating that there is no strong residual cross-sectional dependence after the common factor correction. These are viewed as robustness evidence in addition to the primary evidence provided by the CS-ARDL estimation, which also has some collinearity conditions among common factors.

Table 9: CS-ARDL Robustness Results

Variable	Short-run B	p	Long-run B	p
NRR	-.01101	.248	-.02800	.337
RNE	-.00752	.299	-.01915	.255
NRR $\times$ RNE	-.00038	.628	-.00154	.507
lnGDP	0.0674	.823	0.1932	.574
IND	0.0064	.192	0.0051	.255
Error-correction term	-1.0555	< .001	—	—

Note. The error-correction coefficient is negative and statistically significant, indicating convergence following disequilibrium. The post-estimation Pesaran test gives $CD = -0.232$, $p = .817$. The CS-ARDL output also reports collinearities among some estimated components; this model is therefore treated as a robustness check rather than the primary specification.

The overall results are consistent in one key aspect across both the main and robustness specifications: renewable energy is statistically strongly tied to its direct reduction of CO₂ emissions in the Driscoll-Kraay models, while there is no robust statistical evidence that renewable energy weakens the link between natural-resource rents and CO₂ emissions. Economic growth and industrialization, on the other hand, continue to be significant positive factors in the environmental pressure of the economies of the selected resource-intensive Asian economies.

Discussion

According to the results, the environmental factor that is the most constant in the model is renewable energy. The increase in renewable energy use is correlated with the decrease in CO₂ emissions and remains strong when controlling for trade openness and urbanization. This result aligns with the latest regional and global studies in ASEAN and across countries, indicating that higher adoption of renewables is associated with better environmental outcomes, as reducing reliance on carbon-intensive energy sources is beneficial to the environment (Kostakis, 2024; Lin et al., 2024; Tran et al., 2024). The robustness of this coefficient over the two specifications of Driscoll–Kraay further supports the primary empirical result of the study.

However, in the primary model, there is no statistically significant direct relationship between natural-resource rents and CO₂ emissions. This is also in contrast to those studies which maintain that resource rents boost emissions by driving extraction and dependence on fossil fuels, or that they stimulate production with resource-intensive methods (Lin et al., 2024; Nguyen et al., 2023). The difference implies that the impact of dependence on the environment might vary from country to country, and it might rely on the energy structure, type of resources, technology, and institutional conditions (Gillani et al., 2026; Sun et al., 2025; F. Wang et al., 2025). There is also no statistically significant relationship between natural-resource rents and renewable energy. So, while renewable energy is directly linked to reduced emissions, the evidence is not conclusive that it leads to a substantial impact on the NRR–CO₂ relationship.

The finding is different from the international evidence that the environmental impact of renewable energy could be different depending on the resource rents (Q. Wang et al., 2024). Within the current sample, renewable energy seems to have only a direct emissions-reducing pathway. CO₂ emissions are positively related to GDP per capita and industrialization. This means that the economic growth and development of the resource-intensive Asian economies are still tightly tied to high-carbon-intensity production. The same has been observed in Asian and resource-dependent economies, where the economic growth that has been built on fossil fuel dependence can be undermined by continued dependence on these resources (Nguyen et al., 2023; Tran et al., 2024).

A more conservative picture of the long run is provided in the results from the CS-ARDL. Although the adjustment coefficient is negative and significant, the long-run coefficients of renewable energy, natural-resource rents, their interaction, GDP, and industrialization are statistically insignificant. Hence, the high level of relationships seen in the primary Driscoll–Kraay model should be interpreted as strong within-panel relationships instead of strong long-run causal effects.

Conclusion and Policy Implications

Conclusion

This study explored the causal linkage between natural-resource rents, renewables consumption, and CO₂ emissions in the nine resource-intensive Asian economies in 1995–2022. Fixed effects with the standard errors of Driscoll–Kraay and CS-ARDL were used as the main estimator and additional robustness framework, respectively.

The main conclusion is that there is always a reduction in CO₂ emissions attributable to renewable energy. Such a link persists even when accounting for the effects of trade openness and urbanization. In contrast, the direct impact of natural-resource rents on emissions is not statistically significant, and the relationship between natural-resource rents and renewables has no significant effect. The results thus indicate that renewable energy plays primarily in a direct emissions-reducing channel, rather than in a substantial way altering the impact of resource rents on emissions.

The main model shows that CO₂ emissions are positively related to economic growth and industrialization. This suggests that growth of the sampled economies is still strongly associated with carbon-intensive production and energy consumption. The CS-ARDL results, on the other hand, offer a more conservative long-run view because the long-run coefficients are not statistically significant, but there is a statistically significant adjustment term showing convergence after short-run shocks. The overall results highlight the critical role of renewable energy in a pro-ecological economy and demonstrate that the effects on the environment of the development of renewable energies alone are not enough to shift the environmental impact of economic structures based on resources.

Policy Implications

The results have a number of practical consequences. Policymakers should speed up the reduction in the use of conventional energy sources by investing in renewable energy technologies, particularly solar and wind, upgrading transmission and distribution infrastructure, increasing storage capacity, and enacting policies that incentivize renewable energy. There is a strong negative correlation between consumption of renewable energy and CO₂ emissions, indicating the potential to reduce environmental pressures through increased use of renewable energy.

Second, in resource-rich economies, the proportion of natural resource revenues invested in energy diversification and low-carbon infrastructure should be increased. These fossil fuel revenues can instead be used to fund new investments in clean energy, energy efficiency, clean transportation, and technological upgrades.

Thirdly, emissions are positively correlated with industrialization, meaning there is a need to move towards cleaner industrial development. In addition to promoting the development of renewable energy, environmental policy should aim at enhancing the energy efficiency of industry, as well as the use of cleaner production technologies and a lower carbon intensity of industrial

production. Lastly, there is some evidence of the heterogeneity of slopes, indicating that an overall regional policy approach can be insufficient. The energy system, resource dependency, industrial structure, and development level of countries vary, so transition strategies need to be tailored to the national context rather than following a common policy model.

Limitations and Future Research

This study has a number of limitations. The analysis focuses on the nine resource-intensive Asian economies and should not be extended to all Asian or resource-rich countries. Further, aggregate natural-resource rents encompass all forms of natural resource rents, including oil, gas, minerals, coal, and forest rents, which can vary in terms of their environmental impacts. Future research may be able to disaggregate resource rents by specific category, and also include institutional quality and environmental regulation as other moderating variables, and analyze the resource-intensive economies from various regions. Country-specific analyses could also present greater detail on why renewable energy has superior environmental benefits in certain economies compared to others.

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