



Research Article

Assessing the influence of economic growth, natural resource utilization, and the energy relationship on environmental quality in five Asian nations

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ABSTRACT

This study explores the complex linkages between natural resources, economic growth, energy usage, and CO2 emissions in six Asian countries from 1993 to 2022. Through rigorous analysis, it seeks to uncover the key drivers of sustainable development and provide actionable insights for policymakers to address environmental challenges while promoting economic growth. It employs panel data analysis and applies various econometric techniques to analyze the dynamic flow of relationships among the variables of the economic and environmental context. To examine the cross-sectional dependence and the included variables' impacts on CO2 emissions on short—and long-term, the paper uses the Pesaran Cross-Dependent test while utilizing the Dynamic Common Correlated Effects (CS-ARDL) estimator. The study shows a cross-section temporal correlation between economic and environmental factors in the region that symbolizes the interconnection of the countries' economies. Renewable energy and non-renewable energy are found to have a direct positive effect on economic growth. In contrast, natural resource rent is found to have no or, in fact, negative or insignificant effect. This study has also found a significant positive relationship between economic growth and CO2 emissions to support the call for green economic development initiatives. Specifically, it is found that renewable energy consumption decreases CO2 emissions, thus reinforcing the need for shifting towards green energy. The research findings show the need to develop region-specific solutions that consider the socio-economic and ecological environment of Asian countries. It supports green finance laws, encourages investment in renewable technologies, and improves governance standards for sustainable development, ensuring future sustainability. Given that this research highlights the significance of the conservation and utilization of resources and the development of useful energy, this paper offers guidance for the policymakers working to reach the region's United Nations Sustainable Development Goals (UNSDGs).

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1. INTRODUCTION

The relationship between natural resources and economic performance and the environmental consequences has been the focus of discussion for several decades. Originally, countries depended much on their stock of natural resources, including Timber, minerals and water sources, for economic growth (Azam et al., 2023). However, this approach often serviced environmental destruction, resource exploitation and social injustice (Carney, 2023). Thus, more and more economic scholars and policymakers, to avoid blindness to externalities, have started looking for methods for achieving economic growth with efficiency. Some of the focal issues in this area are environmental pollution, natural resource depletion, energy shift towards renewable sources and issues of equity (Roḥab et al., 1996; Mahsud, 2011; Turk, 2016; Režný & Bureš, 2019). Analyzing the over-sustenance of natural resources elsewhere than ecosystems' CAP has brought countless adverse impacts on the natural background, for instance, ecosystem degradation, loss of species variety, and climate alterability (Mondal et al., 2022; Titumir et al., 2023). Secondly, the problems of exhaustibility of such resources and increasing population pressures lead to scarcity of resources and frequent conflicts over the share (Mahmud & Islam, 2023).

These challenges indicate that governments worldwide have been experiencing pressure to shift to renewable energy sources and adopt green technology-based economic reforms. It is, therefore, essential for changing greenhouse emissions, maintaining sustainable energy systems, and promoting economic growth (Kabeyi & Olanrewaju, 2022). The UN Report of 2023 estimates that clean energy contributed about 10 percent of the GDP in the world in 2023. Renewable energy sources have positively influenced major macroeconomic indicators -GDP, Industrial Production, CAPM, and CDP (Chou et al., 2023). Furthermore, the renewable energy sector has created employment and strengthened the local community regarding energy security (Clausen & Thomas, 2020). According to IRENA's finding in 2016, advancing the share of renewables by a factor of two could boost global gross domestic product by as much as 1% compared to a 2003 baseline. However, such a shift must be well thought-out, well-funded, and encompassing emotional and managerial policies that enable a proper blend of economic growth and ecological conservation (Chou et al., 2023). When entering the era of industrialization and experiencing the growth of the population and energy demand among countries, especially in the region of South Asia, it is necessary to understand the cross-linkages between NR, energy, and economic advancement, which forms the basis of sustainable development and green finance strategies (Khan et al., 2020; Mughal et al., 2022).

The main research objectives include:

- To examine the effect of natural resource rent on economic growth.
- To explore the impact of renewable and nonrenewable energy consumption on economic growth in six Asian countries.
- To observe the relationship between economic growth and CO₂ emissions.
- To assess the effect of renewable and nonrenewable energy consumption on CO₂ emissions.
- To explore the role of natural resource rent in determining CO₂ emissions.

2. LITERATURE REVIEW:

The literature review discusses interactions between natural resources, economic development, and energy processes, focusing on introducing green finance in South Asian nations. This paper examines how such interactions influence sustainable environmental management, economic growth, and the shift towards the use of renewable energy.

2.1. H1: RENEWABLE ENERGY CONSUMPTION POSITIVELY IMPACTS ECONOMIC GROWTH.

A bibliometric analysis of Chou et al. (2023) showed a relationship between the increase in renewable energy intensity and economic performance in terms of GDP, industrial output, and technological advancement. This is consistent with the new paradigm in economic thinking identified by Barbier (2003), which positively determines natural and environmental resources as assets in underpinning the economy.

In addition, Byaro et al. (2022) supported the government's effort to adopt renewable energy sources for sustainable development in Sub-Saharan Africa. This information was outlined in the introduction to the 2016 IRENA report, which argues that doubling the contribution of renewable energy could potentially increase the global GDP by up to 1% compared to 2003. Therefore, all this evidence would suggest a positive relationship between economic growth and renewable energy consumption.

2.2. H2: NONRENEWABLE ENERGY CONSUMPTION POSITIVELY IMPACTS ECONOMIC GROWTH.

According to the study done by Le et al. (2020), both renewable and non-renewable energy sources are found to affect economic growth. However, the long-term gainfulness of this coexistence is doubtful, given the environmental impact. According to the resource-based theory, countries replete with natural resources, including non-renewable energy, may realize higher economic growth rates (Auty, 2000). This is well illustrated by the Middle East and North African oil-rich countries benefiting from resource revenues (Al-Rawashdeh et al., 2013).

However, Frankel's (1995) concept of the "Dutch Disease" suggests that heavy reliance on resource exports (like oil) can lead to an increase of the exchange rate, making other sectors less competitive and resulting in an unbalanced economy. This indicates that while non-renewable energy consumption might positively impact economic growth in the short term, but its long-term effects are more complex and potentially detrimental.

2.3. H3: NATURAL RESOURCE RENT POSITIVELY IMPACTS ECONOMIC GROWTH.

The literature presents conflicting views on this hypothesis, reflecting the complexity of the relationship between economic growth and natural resources. The resource-based theory supports a positive impact, suggesting that countries with maximum natural resources can have higher economic growth rates (Auty, 2000). However, the resource curse theory, as discussed by Wang et al. (2021), proposes that abundant natural resources can hinder

economic development. Kim and Lin (2015) found that, on average, economies with more natural resources are inclined to develop slowly, but the effects vary significantly across countries.

José and Lauter (2016) found that natural resources are insignificant in forecasting African economic development. The meta-analysis by Havranek et al. (2016) reveals that approximately 40% of empirical studies find no effect, 40% find a negative effect, and 20% find a positive effect of natural resources on long-term economic growth. Factors such as institutional quality, investment strategies, and the type or scarcity of resources play crucial roles in determining the impact of natural resource rent on economic growth. The Institutional Complementarity rule (Bilan, 2019) suggests that high-quality institutions enhance the positive impact of natural resources on growth.

2.4. H4: ECONOMIC GROWTH LEADS TO HIGHER CO2 EMISSIONS.

The literature generally supports this hypothesis, albeit with some nuances. Awosusi et al. (2021) found a positive link between emissions and economic growth in Colombia from 1970 to 2017. This supports the Environmental Kuznets Curve (EKC) hypothesis, which states that there is an inverted U-shape between economic development and environmental pollution (Caviglia, 2021). Alieu Gibba and Muhammad Kamran Khan's article on the impacts of Growth on the Environmental Quality of the Gulf Cooperation Council (GCC) members analyzed in 2023 also explains this relationship between growth and environmental quality. However, the correlation cannot be linear and is mediated, for instance, by trade openness, natural resource intensity, or the share of renewables in the energy mix (Ghalieb et al., 2024). Hau, during economic growth and development emanating from developing economies, the correlation between CO2 emissions and economic growth tends to rise. However, the steepness of the slope may vary with time. These shifts towards cleaner technologies and greener forms of producing and consuming electricity can, over time, break the linkage between economic and emissions growth, as Güney (2019) argues.

2.5. H5: RENEWABLE ENERGY CONSUMPTION CAN LEAD TO LOWER CO2 EMISSIONS.

The evidence available in the literature fully supports this hypothesis. In their research, Wen et al. (2022) noted that using renewable energy positively impacted decreasing environmental output in various African nations from 1990 to 2019. Such findings were observed in the different studies and regions of the world, as established in the literature above. For instance, Zhang (2023) observed that since green finance involves financing sustainable energy, including renewable energy, green financing programs have reduced the commercial CO2 emissions of countries like India, Bangladesh, and Pakistan from 2000 to 2018.

Similarly, in the study by Awosusi et al. (2022), there was a clamour for adopting renewable energy for development. In addition, Chou et al. (2023) followed up with a study to reveal that using renewable energies can foster green economic development along with improvements in economic indicators and environmental performance. This aligns with

the global initiatives, mainly the sustainable development agenda and low-carbon economy.

2.6. H6: NONRENEWABLE ENERGY CONSUMPTION LEADS TO HIGHER CO2 EMISSIONS.

All studies to a certain degree, including Wen et al. (2022), who established that higher consumption of non-renewable energy highly contributed carbon emissions in African nations between 1990 and 2019. Güney (2019) discussed how the issue of the environment needed to be managed with an emphasis on the use of diversified form of energy and most importantly the renewables. The analysis also points to the fact that innovation has long been a major factor in cutting emissions of carbon dioxide in the world economy, but largely due to the adoption of cleaner technologies in such sectors as transport. The study by Long et al. (2023) looked at how renewable and non-renewable energy sources impact economic growth and climate change. They pointed out that energy options need to formulate short-run and long-run consequences, however non-renewable energy use lingers with CO2 emissions.

2.7. H7: NATURAL RESOURCE RENT IMPACTS CO2 EMISSIONS.

According to the literature, the nature of this relationship for this hypothesis seems quite nuanced. While the direct impact of natural resource rent on CO2 emissions is often discussed in the literature reviewed above, certain indirect connections signify several factors identified by other sources.

Shabbir et al. (2020) pointed out that the long-run effects of a few natural resources, such as deforestation and CO2 emissions, have a negative effect on GDP growth. This implies a complexity between natural resource utilization, economic enhancement, and discharges. Regarding the sectoral composition of the economy, the idea of the “resource curse” (Wang et al., 2021) and the “Dutch Disease” (Frankel, 1995) suggest that orientation on natural resources may have negative impacts on balances and potentially lead to higher emission levels due to overexploitation and under-diversification.

Shah et al. (2022) analyzed how resource endowment can enhance the adverse effects of income disparities on growth, which could be tied to emissions. Like Alieu Gibba’s (2023) study on the environmental quality of GCC states, natural resource abundance and other factors expectedly depicted the impact on the state’s environmental quality.

The current literature seems inconclusive regarding the dependency of the effect of natural resource rent on CO2 emissions. However, there are suggestions that the effects might be large and mediated by resource management practices, policies, and environmental laws.

3. METHODOLOGY:

This study utilizes annual time-series data from 1993 to 2022 for Six Asian countries. The data was sourced from the "World Development Indicators (WDI)" database. The modern states of Asia included in this study are China, Bangladesh, India, Nepal, Pakistan, and Sri Lanka. Nonrenewable energy consumption is represented as primary energy usage before

oil transport, while natural resource use is shown in table 1 as the total consumption of coal, gas, and oil. Sustainable energy sources, including solar, hydropower, natural gas, and wind energy, are graphically depicted.

Table 1. Variables definition and sources

Variable	Full abbreviation	Sources
CO2	Carbon dioxide emissions (metric tons per capita)	WDI
GDP	Gross Domestic Product 2016 US\$ constant	WDI
RENT	Total Natural Resources Rent (% of GDP)	WDI
NRE	Nonrenewable Energy usage (Kg of Oil equivalent per capita)	WDI
RE	Renewable Energy Usage (% of total energy usage)	WDI

3.1. THE FRAMEWORK OF THE STUDY:

The conceptual farmwork (Fig. 1) and model is specified as $CO_2 = f(RE, NRE, RENT, GDP)$

In the log-linear form:

$$LCO_{2it} = \beta_{it} + \beta_{yit} LGDP_{it} + \beta_{rit} LRE_{it} + \beta_{nrit} LNRE_{it} + \beta_{renit} LRENT_{it} + \mu_{it}$$

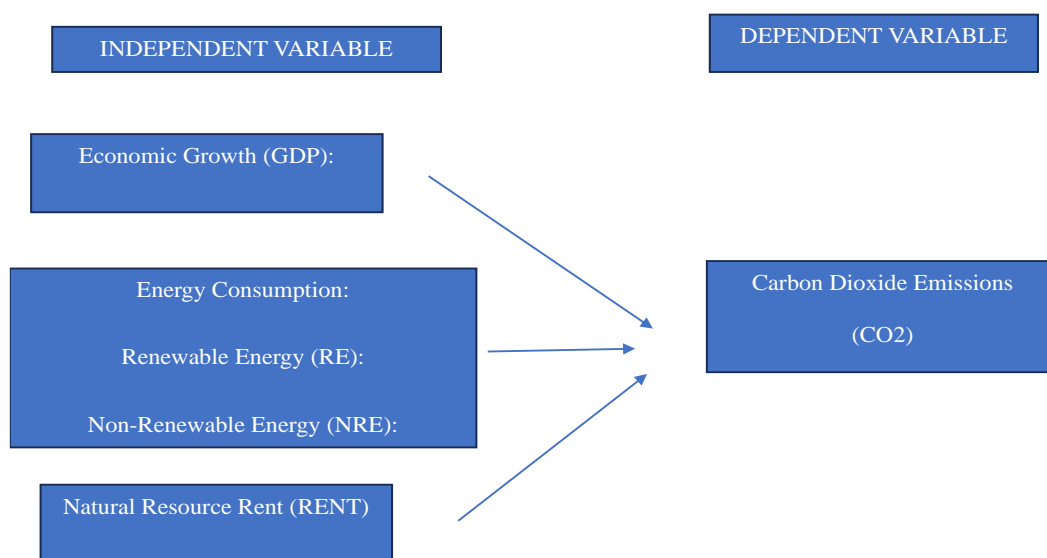


Fig. 1. Conceptual Farmwork

3.2. DESCRIPTIVE ANALYSIS:

When the economic and industrial aspects of the studied nations are compared, China stands out as the most dominant nation. It tops a few metrics, such as the mean natural log of GDP, pointing out the country's large economy. According to table 2 China also has high energy usage (mean 1353.63) and CO2 emissions (mean 4.941) as it is more industrialized and consumes much energy. However, China's renewable energy consumption is the lowest (mean of 19.883%), suggesting a heavy reliance on fossil fuels. The country also shows the highest total natural resources rent (TNRR) with a mean of 3.332, implying significant exploitation of natural resources for economic gain.

In stark contrast, Nepal presents a different profile. Despite having the lowest mean GDP (natural log of 23.606) and energy use, Nepal leads in renewable energy consumption with

a remarkable mean of 86.834%. This suggests a more sustainable energy approach, possibly due to less industrialization and greater utilization of hydroelectric power. Nepal also has the lowest CO₂ emissions (mean of 0.197), indicating a smaller environmental footprint.

India and Bangladesh fall between these extremes. India follows China in CO₂ emissions (mean of 0.068) and is likely in the middle range for other metrics, reflecting its status as a rapidly developing economy. Bangladesh shows lower energy use (mean of 166.56) than China, suggesting less industrialization. Sri Lanka is at the bottom of this table with an average TNRR of 0.179, suggesting that the country relies less on natural resource exports and exploitation for its economy. This may point to a more diversified economy in the future.

The analysis also shows large temporal fluctuations of these indicators for most countries, as evidenced by the standard deviations. For example, using GDP as an indicator, the standard deviation is equal to 0.765, demonstrating the high variability of the Chinese economy. The study's result deliver insights into the relationship between economic development on the one hand and energy and emissions on the other hand in the relevant region. Thus, they emphasize the fact that economic development level and the state of the environment is rather diverse in these Asian countries, which indicates the need for further gradual realization of processes related to the achievement of sustainable development in each country, considering the balance between further economic growth and environmental protection. Some contrasts, especially between China and Nepal, are profound and reflect the capacities and constraints of each nation in shaping sustainable development futures as shown in Fig. 2.

Table 2. Descriptive Analysis

Variables	Obs	Mean	Std. Dev.	Min	Max
<i>Bangladesh</i>					
co2	28	.3	.151	.11	.59
lngdp	30	25.58	.5	24.82	26.45
tnrr	29	.962	.36	.51	1.62
eu	22	166.56	33.042	123.37	227.13
rec	28	46.938	13.688	25.79	70.56
<i>Sri Lanka</i>					
co2	28	.676	.228	.29	1.08
lngdp	30	24.717	.44	24	25.3
tnrr	29	.179	.094	.06	.44
eu	22	430.763	57.205	322.96	535.5
rec	28	59.28	7.692	45.13	74.19
<i>Nepal</i>					
co2	28	.197	.143	.07	.53
lngdp	30	23.606	.368	22.97	24.22
tnrr	29	1.028	.302	.42	1.52
eu	22	342.736	36.105	295.47	425.67
rec	28	86.834	5.553	74.29	93.55
<i>India</i>					
co2	28	1.184	.366	.7	1.8
lngdp	30	27.879	.544	26.98	28.72

Variables	Obs	Mean	Std. Dev.	Min	Max
tnrr	29	2.951	1.243	1.75	7.11
eu	22	464.691	82.723	364.93	630.9
rec	28	41.249	6.575	32.57	51.49
<i>Pakistan</i>					
co2	28	.712	.088	.59	.92
lngdp	30	26.141	.354	25.57	26.71
tnrr	29	1.762	.598	.97	2.89
eu	22	422.712	18.464	392.18	461.6
rec	28	48.449	3.276	42.1	54.2
<i>China</i>					
co2	28	4.941	2.104	2.24	7.76
lngdp	30	29.335	.765	28.01	30.42
tnrr	29	3.332	2.161	.86	9.65
eu	22	1353.633	523.033	788.13	2224.35
rec	28	19.883	7.955	11.34	31.51

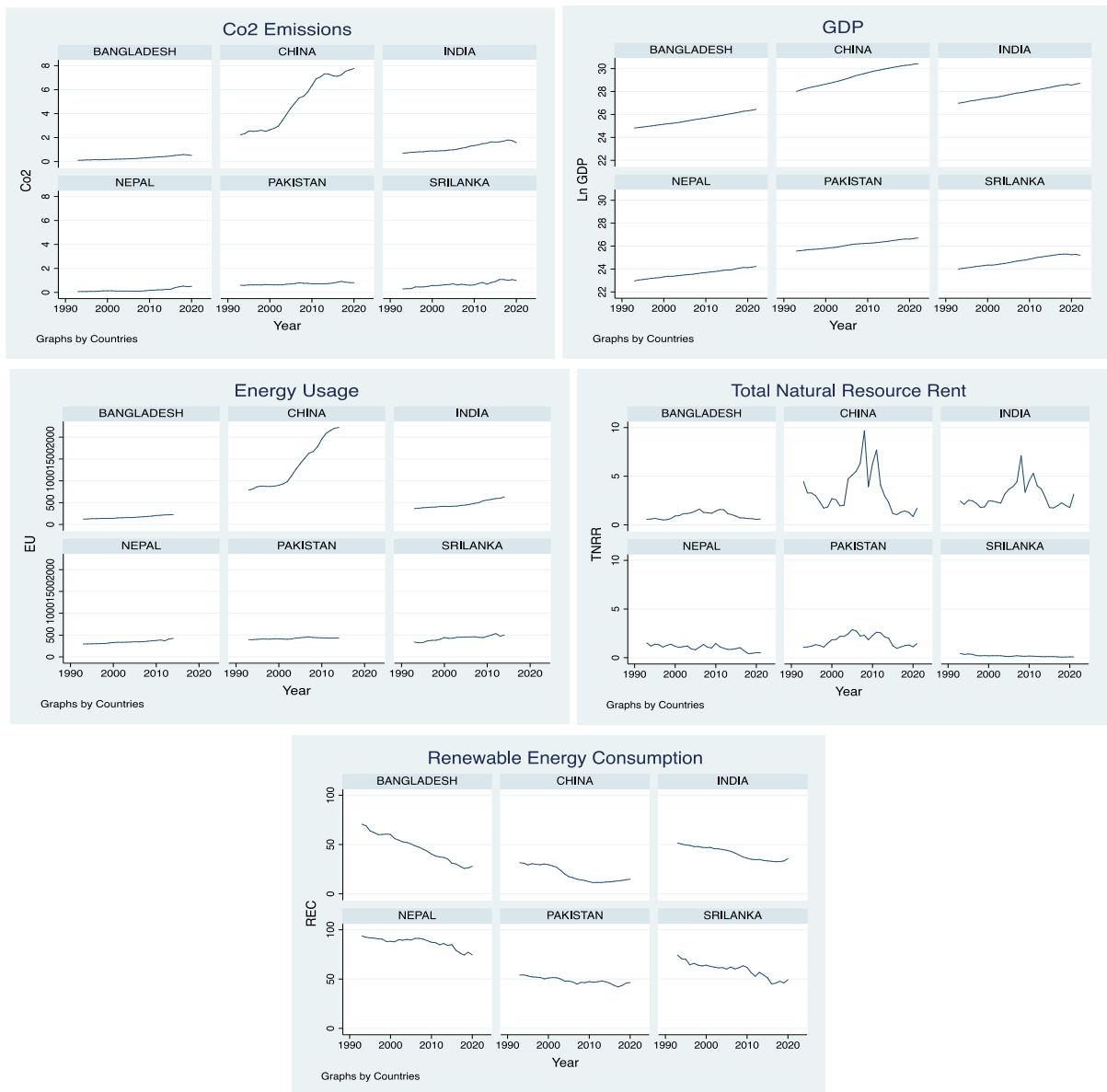


Fig. 2. Variable trend across countries

4. RESULTS

4.1. PESARAN CROSS-DEPENDENCE TEST

The Pesaran Cross-Dependence (CD) test reveals important cross-sectional dependence between the variables across the six Asian countries studied, showing the association between their economic and environmental factors. The test results show extreme cross-sectional dependence for CO2 emissions (CD-test statistic: 14.860, correlation coefficient: 0.818), renewable energy consumption (14.780, 0.814), energy usage (15.310, 0.843), and GDP (18.080, 0.995), all with p-values of 0.000. This points to the fact that fluctuation in these variables in a particular country is significantly related to other variables, implying regional integration of economic activities and the environment. Notably, GDP shows an almost perfect correlation across countries, implying highly synchronized economic activities. Total natural resource rents (tnrr) exhibited a lower, but still significant, cross-sectional dependence (CD-test statistic: 2.310, correlation coefficient: 0.127, p-value: 0.021), indicating a weaker but present association across countries (table No 3). These findings underscore the importance of considering regional interdependencies in economic and environmental policies, as actions taken in one country are likely to have spillover effects on others. The strong cross-sectional dependence observed necessitates using econometric models that can account for these interdependencies when analyzing panel data involving multiple countries. This ensures more accurate and robust results in studies of the region's economic growth, energy consumption, and environmental impact.

Table 3. Pesaran Cross-Dependence test

Variable	CD-test	p-value	corr	abs(corr)
co2	14.860	0.000	0.818	0.818
rec	14.780	0.000	0.814	0.814
eu	15.310	0.000	0.843	0.843
tnrr	2.310	0.021	0.127	0.545
lngdp	18.080	0.000	0.995	0.995

Notes: Under the null hypothesis of cross-section

Independence $CD \sim N(0,1)$

4.2. THE DYNAMIC COMMON CORRELATED EFFECTS (CS-ARDL)

The data used to estimate the models of various independent variables' impacts on CO2 emissions comprise six countries, each with 120 observations over twenty years; therefore, applying the Dynamic CS-ARDL estimator, the short and long-run effects were assessed (Fig. 3). The statistical analysis of the model shows that the total R-squared of the study is approximately 0.23, which indicates that the model's independent variables can explain 23% of the variation in CO2 emissions. However, the mean group R-squared is higher and equals 0.91. As for the overall model fit, the F-statistic of 1.10, when tested against a p-value of 0.40, shows that the model is not statistically significant.

On the other hand, the results also show that renewable energy consumption (rec) impacts CO2 emissions in the short run in the negative direction, with a coefficient of -0.026 and a p-value of 0.044. This reveals that when the consumption of renewable energy is advanced, there is a reduction in CO2 emission, which implies quick positive effects of embracing

renewable energy. On the other hand, other variables, including energy usage (EU), total natural resource rents (tnrr) and GNPP (lngdp), did not produce any significant impacts on the CO₂ in the short term with p values of 0.623, 0.341 and 0.594 respectively.

(Dynamic)	Common	Correlated	Effects	Estimator	-	(CS-ARDL)
Panel Variable (i):	idcode			Number of obs	=	120
Time Variable (t):	year			Number of groups	=	6
Degrees of freedom per group:				Obs per group (T)	=	20
without	cross-sectional		averages		=	15
with	cross-sectional		averages		=	5
Number of				F(90, 30)	=	1.10
cross-sectional lags			1 to 1	Prob > F	=	0.40
variables in mean group regression	=	24		R-squared	=	0.23
variables partialled out	=	66		R-squared (MG)	=	0.91
				Root MSE	=	0.03

Fig. 3. The Dynamic Common Correlated Effects

Table 4. The Dynamic Common Correlated Effects

D.co2	Coef.	Std. Err.	z	P>z	[95%Conf.	Interval]
<i>Short Run Est.</i>						
<i>Mean Group:</i>						
rec	-0.026	0.013	-2.020	0.044	-0.052	-0.001
eu	0.001	0.001	0.490	0.623	-0.002	0.003
tnrr	-0.255	0.267	-0.950	0.341	-0.779	0.269
lngdp	0.213	0.400	0.530	0.594	-0.571	0.998
<i>Adjust. Term</i>						
<i>Mean Group:</i>						
lr_rec	-1.026	0.013	-78.250	0.000	-1.052	-1.001
<i>Long Run Est.</i>						
<i>Mean Group:</i>						
lr_eu	0.001	0.001	0.540	0.587	-0.002	0.003
lr_lngdp	0.194	0.394	0.490	0.622	-0.578	0.967
lr_tnrr	-0.239	0.251	-0.950	0.340	-0.731	0.252
<i>Mean Group Variables: Cross Sectional Averaged Variables: co2 rec eu tnrr lngdp</i>						
<i>Long Run Variables: lr_eu lr_lngdp lr_tnrr Adjustment variable(s): lr_rec (rec)</i>						
<i>Heterogenous constant partially out.</i>						

Among these adjustments, lr_rec is highly significant with a coefficient of -1.026 and a p-value of 0.000, illustrating a profound correction mechanism of renewable energy consumption to reach the steady-state equilibrium. Any divergence from the long-run

relationship between CO₂ emissions and renewable energy consumption can be corrected immediately, pointing to a more dynamic relationship (see Table 4).

Finally, it is significant to mention that, in the long-run, all the independent variables also have a direct positive relationship with CO₂ emissions as it has been identified in the short-run scenario (Zhang, 2023). The energy consumption has also risen through the years, negating the increased need for energy from renewable sources with reduced emissions. Nevertheless, energy usage (lr_eu), GDP (lr_lngdp), and total natural resource rents (lr_tnrr) once more have no causal long-run impacts on CO₂ emissions, with p values being 0.587, 0.622 and 0.340 respectively.

Consequently, the findings affirm that the intake of renewable energy significantly reduces CO₂ emissions in the long and short run. Another characteristic is that other variables with economic and resource characteristics have no direct effect on the result, which reflects the change in the relationship between CO₂ emissions and renewable energy over time through the significant large adjustment term. Based on these outcomes, it became clear that enhancing renewable resources as part of the development policies is crucial for future environmental sustainability in the six examined countries.

4.3. CONCLUSION AND POLICY RECOMMENDATIONS

The research fully developed the relations between CO₂ emissions, economic growth, use of natural resources and the application of renewable energy sources in six Asian countries over the period 1993-2022. Leaving the Lagrangian approach, it employed the negotiating Pesaran Cross-Dependence Test joined with the Dynamic Common Correlated Effects (CS-ARDL) method to provide both analyses of long-run and short-run effects consistent with the SDG objectives of the United Nations. The work confirmed cross sectional connections between the countries concerned, thus underlined multiregional approaches in tackling such economic and environmental concerns. Hypothesis H1 and H2 was supported by the results showing that both renewable and non-renewable energy sources affected economic growth while natural resource rent were not found to have an impact on economic growth. This implies that improvement of the governance and sustainable use of resources can augment the positive impact of these rents on development. Further, the study established a positive relationship between economic development and CO₂ emission (H4), which indicates that growth has environmental consequences.

The research also suggested that the CO₂ emission could be decreased in short and the long run with the expanded use of renewable energies, thus supporting hypothesis H5. Nonetheless, there was no short-term effect of non-renewable energy consumption on emissions; it only affected emission negatively in the long-term and partially supported H6. That there is no significant relationship between the dependent variable and natural resource rents as postulated in H7 outlined proved that emissions' result could be shifted through efficient resource use hence supporting the use of the resource rent weapon for sustainable economic development. The research also suggested the expansion of renewed resources such as wind, solar and hydropower along with better environmental regulation. Better governance and education are factors that must be applied to oppose

the reduction of the quality of the living under the pressure of the resource degradation. To find sustainable ways for Asia to meet the SDGs, the study has recommended regional policies, establishment of green finances as well as appropriate renewable resources technologies based on demographics and regional or physical environments of the region.

Author Contributions:

I, Syed Muhammad Ahmad Hassan Gillani helped my coauthor Ms. Khdiya Sarwar in conceptualized the main idea, aiming and helped in data analysis and review writeup. Asad Javed carried out a comprehensive literature review, developed the conceptual framework, and undertook data collection and completed paper write up. Mr. Asad Javed and Ms. Aiza Khan offered significant contribution in the write up, referencing, proofreading, and offered valuable recommendations to improve the paper's quality.

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Conflicts of Interest:

I declare that the authors have no competing interests, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

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