American Journal of Environmental Economics (AJEE)

ISSN: 2833-7905 (ONLINE)

VOLUME 4 ISSUE 1 (2025)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Environmental Economics (AJEE)

Volume 4 Issue 1, Year 2025
ISSN: 2833-7905 (Online)
DOI: https://doi.org/10.54536/ajee.v4i1.4050
https://journals.e-palli.com/home/index.php/ajee

Harnessing Green Investments for Sustainable Prosperity and the Role of Renewable Energy in Driving Economic Growth and Development in South Asia

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Article Information

Received: November 18, 2024

Accepted: December 22, 2024

Published: February 06, 2025

Keywords

CO_2 Emissions Reduction, Economic Growth, Green Job Growth, Renewable Energy, Sustainable Development

ABSTRACT

This study examines the impact of renewable energy investments on economic growth in South Asia, a region grappling with rapid economic expansion and environmental degradation due to heavy reliance on fossil fuels. This paper employs panel data from 1998 to 2022 and 15 emerging countries to examine the nexus between RE consumption, economic growth, CO_2 emissions, and energy access using GMM and fixed-effects models. These findings suggest that increasing 1% of renewable energy consumption will increase GDP by 0.072%, while increasing 1% of CO_2 emissions will reduce GDP by 0.3%. Besides, renewable energy investments are expected to contribute to the generation of 2.98 million green job opportunities by 2035. The study shows that renewable energy can decrease emissions, increase energy security, and create jobs. Nevertheless, there are limitations like capital-intensive requirements and a lack of proper infrastructure and policies that have to be overcome. Therefore, the study supports the proposition that the sustainable development of renewable energy in South Asia depends on considerable policy intervention, technological improvement, and investment in infrastructure.

INTRODUCTION

The South Asian countries—India, Pakistan, Bangladesh, Nepal, Sri Lanka, Bhutan, and the Maldives—are at that awkward juncture where everyone wants to dream of economic success but has to wake up to ecological imperatives. According to the International Energy Agency (IEA) (2022) economically, this disputed region has been growing; India's GDP, for instance, has been growing at a 6.8% annual rate from 2010-2020. Nevertheless, this set growth rate has been achieved at a price, as greenhouse emissions and degradation of resources have escalated in a similar manner. The South Asia region has demanded an increase in energy of about 3% per year over the last two decades and greatly increased fossil fuel use (Saeed & Siraj, 2024). This dependency leads to environmental deterioration and makes economies vulnerable to fluctuations in energy prices.

Renewable energy comes out as a viable solution when it comes to economic development without affecting the environment. As stated by the International Renewable Energy Agency (IRENA) (2023), renewable energy investment might lead to the generation of up to 1,500 000 new jobs in South Asia by the end of 2030, especially in the sphere of solar and wind power. Also, the increased use of renewable energy sources improves energy security due to decreased importation of fossil energies, balance of trade, and sustainable growth. However, South Asia still has not a significant level of renewable energy source adoption. Currently, the share of renewables is still only 12 percent of the total energy consumption in the region, while the global average is 29 percent (Hassan *et al.*, 2024). This has been occasioned by lack of capital, poor infrastructure, and bureaucratic challenges. According to the World Bank (2016), out of the total number of potentially feasible renewable investment projects in the region, about 60 percent of those projects remain unfunded because of perceived risks and a lack of enabling policies (Rana & Gróf, 2022). Furthermore, legacy grid structures inhibit the management of variable renewable electricity generation, which requires significant investments in upgrades and extensions.

The economic effect of renewable energy investments is therefore not straightforward. Renewables can be used as a backstop to the instability of the prices of fossil fuels, leading to a reduction in the unpredictability of energy costs. The Senior Energy Economist Outlook (2022), indicates that renewable energy can lead to a reduction in energy costs, with potential savings of up to 20% compared to traditional fossil fuels. In addition, renewable energy projects seem to have more investment concentrated in capital, although operating costs are relatively low over the lifecycle of the projects. Given that energy demand in South Asia is expected to increase by about 50% in the next twenty years, the shift to renewable energy could greatly help stabilise and diversify the energy supply (Rana & Gróf, 2022). Furthermore, renewable energy investments can lead to an improvement of the trade balance due to reduced energy importations since South Asia's trade balance of payments, the most cited challenge, is a major deficit in fossil fuels. Crude oil imports were 232.5 million tonnes, and import dependence on crude oil rose to 87.7% in 2023-24 (Hindu, 2024). In the case of the economies of South Asia now transitioning towards domestically produced renewable energy, it would only be a great bonus for their energy security imports.

Another influential factor that defines the further role of

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renewable energy in the economic growth of the countries is the generation of green jobs, which has been recognised as a potential for South Asia. According to Xie (2024) the renewable energy sector is more labor-intensive than fossil fuels, offering substantial employment potential across various stages of the value chain, from manufacturing to maintenance. Shifting towards a green economy in South Asia could lead to about 2.98 million green jobs for the transition up to 2035, especially focusing on solar and wind sources (Gulagi, 2023). This change to green employment could help build employment in the area for the high unemployment rate, particularly of youths, and reduce poverty in the rural areas. Furthermore, the skill development likelihood attends to the overall motivation of creating a modern industrial base and promoting heterogeneity in the South Asian economy by supplying the demand for renewable energy niches that are expected to arise in the emerging green economy marketplace.

The social benefits of investing in renewable energy sources are similar in regard to carbon emissions and air quality. South Asia is ranked among the top continents in terms of emission of greenhouse gases. For instance, Olivier *et al.* (2017) India contributed 2 giga tons of CO_2 equivalent emissions in 2020, and this represented 7% of global emissions. This breaks the facts that the region largely relies on coal energy, a fuel that contributes to nearly 40% of the energy mix and which has been attributed to air pollution and health costs. According to the Organisation for Economic Co-operation and Development (OECD) (2016), it was anticipated that polluted air kills over 1.5 million people from South Asia every year, which makes the provision of clean energy crucial. Switching to green energy is possible and can help decrease the levels of greenhouse gases; research suggests that carbon dioxide emissions could decrease by 30% in case South Asia maintains its renewable energy goals till 2030 (Pandey & Asif, 2022). In addition, through the utilisation of wind and solar power, most of which have less impact on the natural environment as a result of the construction of wind and solar farms as opposed to the conventional sources of energy like the fossil fuels in the region.

However, the changeover to a green economy in South Asia is not easy. Gielen *et al.* (2019) found that the renewable energy industry needs a large fixed capital investment, technological advances, and supportive policies. South Asian grids are usually ageing and weak in terms of flexibility for the incorporation of stochastic resources such as PV and wind power. For instance, Hassan *et al.* (2024) revealed that the current capacities to transmit and resize transfers of renewable energy in rural areas are almost completely inadequate, as shown in the grid upgrade and development (Shahbaz *et al.*, 2020). Furthermore, there are some financial constraints, such as political and economic risks, that compel shifts in policies and markets within the renegotiation of renewable energy investment, which scare both local and international investors. The solution of these problems presupposes overcoming the policies designed to involve private subjects, minimising the potential dangers of investment, and developing renewable energy sources.

This research will reveal the correlation of socio-economic change and pro-environment investment in the South Asian countries based on the promotion of renewable energy. Dai *et al.* (2024) found that the association between renewable energy usage, GDP per capita, employment rate, and CO_2 emissions with the largest countries. Specific objectives are to identify and analyse the correlation between RE and economic GDP to assess the implications of a change in energy mix on the stability of the economy and the balance of the payment stream, to identify the environmental effects of RE, and the reduction of emission rates for CO_2 and an improvement in air quality, and to review existing policies and laws regarding the consumption of large-scale RE. Thus, this paper provides findings and analysis with policy implications for transitioning South Asia to a green economy aligned with global conditions.

LITERATURE REVIEW

Renewable Energy and Economic Growth in South Asia

Renewable energy consumption and economic development in South Asia have emerged as a central focus of concern for scholars of regional development in assessing the costs and benefits of such a transition. Timmons (2018) stated that the economic advantages of RE are supported by many studies that focus on promising economic effects of stable energy prices, increments in GDP, and decreased exposure to the fluctuations in fossil fuel prices. Muneer *et al.* (2005) found that switching to renewable energy could actually cut costs by about 20% to traditional fossil fuels because they have inherently lower overhead costs. Renewables are capital-intensive at the beginning, but their operational costs are relatively low compared to fossil fuels, which need constant fuel feedstock and whose prices are volatile (Chaudhary *et al.*, 2015). In a global context, and specifically for a region like the South Asian, where global oil and especially coal price hikes can undermine all types of economic resilience, shift can be seen as a form of energy and economic security.

The Indian solar power industry gives the possible GDP growth contribution from renewable energy with the expectation that expansion of renewable energy can add one percent to the GDP by 2030 if backed effectively by relative policy (Teske *et al.*, 2019). The economic imperative for a South Asian green energy solution is even more urgent for the region's emerging economies since green energy sources provide an opportunity to self-generate resources for development instead of depending on importing them. Similarly, Bangladesh has planned for the purchase of 40% renewable energy by 2041 to reduce dependency on imported fossil fuels, which will lead to a saving of $1.6 billion per year (Usman *et al.*, 2024). Such case exemplars initiate evidencing the general regional benefits of renewables in increasing economic growth with a tendency to improve trade deficit issues due to the high import of fossil fuels.

A great potential source of economic benefits from the use of renewable energy is from employment creation, which is arguably the largest impact that has come with the use of renewable energy. Shah & Solangi, (2019) highlighted that the globalisation of the renewable energy sector and the extensive use of solar and wind energy are much more influential than the exhaustive use of fossil fuel in creating jobs in the process of its production, the supply channels, installation, and even maintenance. Reflecting a major achievement of the renewable energy system in India, the employment level witnessed an estimated one million two lakh in 2023, as per the 2024 Annual (Nguyen *et al.*, 2024). These employment creation prospects are especially valuable for South Asian countries, as most of the region still struggles with high levels of unemployment, particularly among the youth from rural farming areas. Pakistan's renewable energy policy to add 30% renewable capacity by 2030 envisions employment generation that will help lift people out of poverty in the region and boost rural income generation (Teske *et al.*, 2019). Employment in renewable sectors also promotes value addition towards emerging green technologies in the context of South Asia's industrial development and skill demographics.

One more extensively discussed aspect in the literature is the impact of renewable energy on trade balance and energy security. Fuhr, (2021) found that fossil fuel imports are some of the leading trade deficits affecting the South Asian countries, meaning that these economies are vulnerable to threads arising from global market fluctuations. For instance, India's import of oil was valued at $ 120 billion in 2021 and directly impacts the country's forex reserves coupled with trade deficits and surpluses (Ghosh *et al.*, 2024). Diversifying the South Asian energy mix through renewable sources at home is pivotal to reducing the political volatility of its oil imports, therefore smoothing trade imbalances. Exploitation of domestic renewable energy in Bangladesh and Nepal has the potential to reduce fossil fuel imports by about 30 percent by 2035, which will be a great relief to these economies (Nansai *et al.*, 2021). In addition to this, reliance on renewable energy sources to increase energy independence adds to the nation's security because more energy supply risks are imported, which affected South Asian countries' balances of trade and economic growth.

Environmental and Health Implications of Renewable Energy Adoption

The consequences of renewables on the environment, and more specifically on carbon dioxide emissions, have been analysed exhaustively, and several studies suggest that South Asia can significantly benefit from using renewables to leave a lesser carbon footprint. However, countries of the South Asia region continue to make a significant carbon footprint, where India, for instance, emitted 7% of global CO_2 emissions in 2020 (Anwar *et al.*, 2021). Given the fact that coal is heavily relied on in South Asia for most of their energy needs, conversion to renewable energy will therefore help minimise emissions. It is expected that if India, Pakistan, and Bangladesh reach the target of renewables proposed for 2030, South Asia may reduce regional CO_2 emissions by 30% by 2030 (Lanzi *et al.*, 2018). This reduction is essential for the Paris Agreement and managing climate change outcomes. South Asia is one of the most climate-sensitive areas where sea level rise and other natural disasters pose a real threat to millions of people's existence.

However, other than the emission reduction impact, other main benefits of renewable energy are related to public health. Respiratory diseases, heart diseases, lung cancer, neurological disorders, and birth defects are some of the health hazards related to air pollution in South Asia caused by coal-fired power plants. In the same year, air pollution leads to more than 1.5 million deaths of people across the region (Utturkar *et al.*, 2024). Wind and solar energy sources are very clean in the sense that they emit nearly zero air pollutants, unlike coal and oil, hence better air quality and significant health cost reductions. By comparing coal to solar energy, the authors developed estimates that the part per trillion of pollution decreases by 35%, aimed at lowering respiratory and cardiovascular diseases by as much as 25% (Rasul, 2016). These health benefits are especially relevant in growing populations in cities where air pollution regularly crosses dangerous levels, thus worsening healthcare and general wellbeing. Moreover, Chel and Kaushik, (2011) an increase in air quality has other indirect impacts on economic stability in the region in terms of the cost of doing business, such as an increase in worker productivity due to improved health as well as decreased health costs (Ghosh, 2023).

Environmental benefits of renewable energy also include the preservation of water and land resources, which is essential in South Asia, where most countries depend on agriculture. Nasirov *et al.* (2015) found that fossil-based electricity generation, especially coal power plants, and requires a lot of water for cooling and extraction. While, on the other hand, the usage of renewable resources like solar power and wind power involves very little usage of water in comparison to the non-renewable technologies. According to Sarkar and Singh, (2010) water insecurity risks linked to poverty and climate change in South Asia are on the rise, and these jeopardise agricultural production and food security. Using solar energy in the agricultural sector could increase water consumption by almost 40%, which could help in managing water in rural areas, which are majorly dominated by agriculture (Azhgaliyeva *et al.*, 2020).

Land use is yet another factor where the utilisation of renewable energy sources has a competitive edge over conventional non-renewable sources. Asif *et al.* (2024) stated that solar and wind power infrastructure like fields and wind turbines require huge areas of land, but these resources establish themselves more compliant with agricultural or pastoral use than the fossil fuel extraction sites, which create significant environmental harm and force people out of their homes. To make efficient use of land, all the South Asian countries should practice "agrivoltaics," which involve putting solar panels over agriculture land so that crops and power can be generated simultaneously (Allison, 2022). Such dual-use systems can increase land efficiency and benefit the local economy, especially where land is considered a valuable resource.

Policy and Regulatory Challenges in Renewable Energy Implementation

However, the polity, government, and society of South Asia have a set of limitations and concerns that make it difficult for it to integrate renewable energy sources on a massive scale. An initial challenge is the issues of costs and capital related to renewable energy sources (Aguero *et al.*, 2017). Concentrating on lower capital intensity projects such as solar and wind, renewable energy technologies are expensive to develop to begin with and consequently inaccessible to investors, particularly in markets where green finance is not well developed. More than 60% of renewable projects in South Asia face financing challenges emanating from perceived high-risk markets and poor policy support (United States Energy Association, 2023). South Asian governments should improve the investment attractiveness of renewable power projects through tax benefits, grants, and lower interest rates on green bonds (Mukherjee & Satija, 2020). India, for instance, in its Green Energy Corridor project, is seeking private and foreign investment in renewable energy infrastructure through the provision of fiscal incentives and relucent transmission infrastructure support (Koutoudjian *et al.*, 2021).

Access to finances and existing regulatory frameworks, as well as infrastructure, remain other substantial barriers to regional renewable energy integration. Infrastructures of energy, including the rural areas in South Asia, are currently blunt to support the variation of renewable energy sources (Choi, 2014). For example, wind and solar resources produce electricity in a stochastic manner and are available only during certain periods of the day, so the grid integration is another crucial point. Mishra *et al.* (2019) stated that flexibility of the grid to absorb variability of renewable could facilitate up to 40 percent rise in accomplishment of renewable energy. Still, regulatory differences across South Asian nations pose challenges in integrating renewable energy, which attracts different policy environments and rules governing land acquisitions that slow down the approval of renewable projects. This is particularly evident in India, where bureaucratic procedures and fluctuating policies on land use have restrained deployment of solar projects; hence the need for harmonised rules that enable implementation of renewable energy projects in the region.

South Asia needs to work closer and align with other regional groupings and key global climate deals like the Paris Agreement for its renewable power strategy. South Asian countries' compliance with international climate change policies is patchy, yet some countries, such as India, have taken transformative measures towards boosting renewable power generation. However, there are others that have been slower, namely Bangladesh and Nepal, as a result of political and financial constraints (Ghosh, 2023). Researchers have underlined the idea of adopting a regional strategy incorporated in the development of renewable energy by South Asian nations through the SARI/EI. Initially funded by the USAID to ensure regional energy market integration, SARI/EI promotes cooperation and energy exchange among South Asian countries. Organisations of such initiatives are important, especially when it comes to helping in the sharing of technical know-how's as well as cutting down on implementation costs as well as accessing international funding through the promotion of a more stable investment environment.

However, transition to renewables entails significant capacity development, particularly in the areas of technology transfer and skilled human resources. These South Asian countries can secure technological collaborations that would introduce new technologies and expertise into the region (Lanzi *et al.*, 2018). For instance, partnerships with peer countries or organisations or even development partners in technology matters such as the International Renewable Energy Association (IRENA) (2023) can enhance skills and enhancements in the adoption and implementation of renewable energy systems. Several studies show that capacity development interventions such as those under the IRENA South Asia Programme may substantially improve technical and operational competency relevant to the scaling up of renewable power projects. These programs aim at capacity building at the country level, in terms of skills development of the local workforce, capacity to develop technical know-how on renewable technology implementation, and institutional capacities that can enable the management and coordination of other aspects of the renewable energy transitions.

MATERIALS AND METHODS

The present work employs panel data that encompass 15 emergent Asian countries, ranging from 1998 to 2022, to assess the relationship between renewable energy investments and economic growth across the sustainable development framework. The analysis includes the following dependent and independent variables: For the dependent variable, we have GDP growth rate (annual %) which reflects economic growth. The independent variables include renewable energy consumption (% of total energy consumption), reduction in CO_2 emissions (total CO_2 emissions excluding land-use change and forestry), access to clean energy (% of population with access to electricity), R&D expenditure in renewable technologies (% of GDP), energy intensity of GDP (carbon emissions per PPP-adjusted GDP), and the growth rate of green jobs (employment in renewable energy sectors). The data sources include the World Bank (WDI).

Table 1: Description of Variables

Variable	Abbreviations	Description	Data Source
GDP Growth	GDP	Annual GDP growth (%)	WDI
Renewable Energy Consumption	REN	Renewable energy consumption (% of total energy)	WDI
CO_2 Emissions Reduction	CO_2	CO_2 emissions excluding LULUCF	WDI
Access to Clean Energy	ACE	Population with access to electricity (%)	WDI
R&D Expenditure in Renewable Technology	R&D	R&D expenditure in renewables (% of GDP)	WDI
Energy Intensity of GDP	EIG	Carbon intensity per PPP-adjusted GDP	WDI
Green Job Growth Rate	GJG	Employment growth in renewable energy sectors	WDI

Descriptive Statistics and Correlation Matrix

To provide an initial insight into the data distribution, the minimum, the mean, variance, and maximum values for each of the variables are reported. Also, the correlation matrix is given to show associations between the variables to ensure that there is not vast multicollinearity, as a preliminary way.

Panel Data Regression Models

Fixed Effects (FE) Model

The fixed effects model, as the name suggests, takes into consideration country features that may affect GDP growth; they include policy factors or geography. It let some coefficients be country-specific but not time-specific. The model is defined as follows:

$Y_{it} = a_i + \beta X_{it} + u_{it}$

where Y_{it} denotes the GDP growth of country i at time t is the country-specific intercept, β represents the coefficients of the independent variables, X_{it} the vector of independent variables, and u_{it} the error term.

Random Effects (RE) Model

The Random Effects (RE) model makes a presumption that certain effects peculiar to a country are random and unrelated to the explanatory variables. This kind of model is used when country differences are thought to be unsystematic and have no relationship with the predictor variables. It is defined as:

$Y_{it} = a_i + \beta X_{it} + \mu_i + u_{it}$

Where a is the intercept term, μ_i is the country-specific random effect, and the remaining terms are as defined above.

Hausman Test

To resolve the identification issue and to select between the fixed effects model and the random effects model, we conduct the Hausman test, which endorses the random/RE estimator against the fixed/FE estimator. The test is based on the following statistic:

$H=(b_{FE} - b_{RE})'(Var(b_{FE}) - Var(b_{RE}))^{-1} (b_{FE} - b_{RE})$

Where a significant test result suggests the FE model is preferred.

Dynamic Panel Data Models (Arellano-Bond)

To tackle issues of endogeneity and serial correlation in our model, we use the Arellano-Bond Generalised Method of Moments (GMM) estimator. This method is suitable for dynamic panel data estimations with endogenous dependent and independent variables. The model is defined as follows:

$\Delta Y_{it} = \beta \Delta X_{it} + \gamma \Delta Y_{(i(t-1))} + \epsilon_{it}$

where ΔY_{it} is the first-differenced dependent variable, ΔX_{it} represents the first-differenced independent variables, and $\Delta Y_{(i(t-1)})$ is the lagged dependent variable included to capture the persistence in economic growth.

Panel Unit Root Tests

We use panel unit root tests like the Levin-Lin-Chu test for each variable to confirm series stationaryness and prevent misleading regressions. Stationarity checks help confirm the reliability of subsequent regression analyses.

Multicollinearity Test (Variance Inflation Factor)

To check for any of the independent variables to be multicollinear, the VIF testing is carried out. This will assist in knowing whether any of the independent variables have VIF values exceeding 10, meaning that there are severe multicollinearity problems. Because high multicollinearity can affect the regression results, any variables exceeding the threshold are examined to enhance the model's stability.

RESULTS AND DISCUSSION

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP	375	5.441	3.996	-14.1	14.231
REN	375	35.497	26.959	.7	91.3
CO2	375	280.507	513.958	-84.949	4066.21

ACE	375	82.62	22.347	8.82	100
RD	375	.408	.478	.027	2.459
EIG	375	2.70e-07	2.70e-07	3.85e-08	1.69e-06
GJG	375	41.058	14.857	9.996	76.015

The descriptive statistics provide an overview of the dataset, which comprises 375 observations for most variables, except for R&D expenditure in renewables (328 observations), indicating some missing data. GDP growth averages 5.44%, with a standard deviation of 3.99%, showcasing moderate variability across the sample. The range extends from significant economic contraction (-14.1%) to rapid growth (14.23%). Renewable energy consumption exhibits notable disparity, with an average of 35.5% and a wide range from 0.7% to 91.3%, reflecting varying adoption levels. CO_2 emissions display substantial variation, with a high mean of 280.5 and a standard deviation of 513.96, ranging from -84.9 to 4066.21, indicating diverse environmental impacts. Access to clean energy is relatively high, averaging 82.62%, though some regions still face significant gaps. Investment in R&D for renewables remains minimal, averaging 0.408% of GDP. Meanwhile, energy intensity and green job growth reflect differing efficiencies and employment progress across regions.

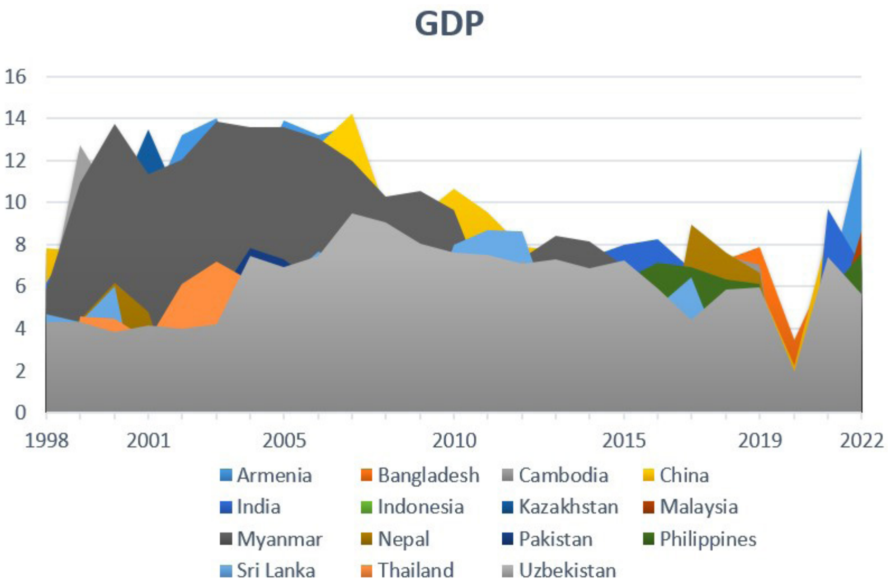

Figure 1: GDP Growth

The Figure 1 illustrates GDP trends across selected countries from 1998 to 2022, showcasing diverse growth patterns. Countries like India and China exhibit consistent economic growth over the years, contributing significantly to the region's overall economic performance. However, some countries show a moderate or erratic growth rate, which shows the different levels of economic security. A notable sharp decline in GDP occurs around 2020, attributable to the global economic disruptions caused by the COVID-19 pandemic. However, a significant recovery is observed in 2022, indicating resilience and post-pandemic economic rebound. The graph highlights regional disparities and the broader economic impact of external shocks on these economies.

The scatterplot matrix displays pairwise relationships between several variables: GDP, renewable energy (REN), CO_2 emissions, access to electricity (ACE), research and development (RD), economic inequality (EIG), and green jobs growth (GJG). It highlights the correlations and patterns between them. For example, GDP shows positive relationships with variables like REN and ACE but exhibits nonlinear or dispersed associations with CO_2 and RD. The REN variable has scattered patterns with other indicators, suggesting complex, potentially nonlinear interactions. Negative trends are visible between CO_2 emissions and ACE or REN, indicating a potential trade-off between environmental goals and emissions. Further statistical analysis is needed.

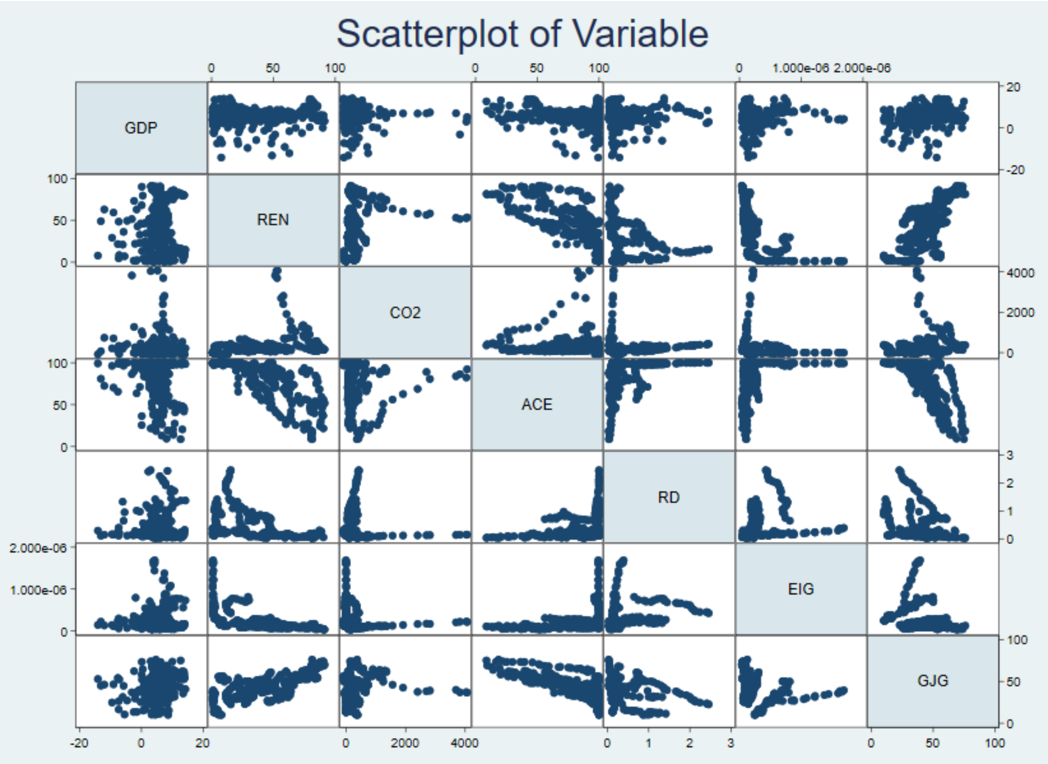

Figure 2: Scatterplot of Variable

Table 3: Matrix of Correlations

Variables	GDP	REN	CO2	ACE	RD	EIG	GJG
GDP	1.000						
REN	0.105	1.000					
CO_2	-0.046	0.310	1.000				
ACE	-0.207	-0.819	-0.200	1.000			
RD	0.059	-0.328	-0.027	0.290	1.000		
EIG	0.101	-0.549	-0.169	0.366	0.264	1.000	
GJG	0.239	0.605	0.018	-0.669	-0.265	-0.223	1.000

The matrix of correlations highlights the relationships between key variables in the dataset. GDP exhibits a weak positive correlation with renewable energy consumption (0.105) and green job growth (0.239), suggesting that economic growth is modestly associated with these variables. CO_2 emissions are positively correlated with renewable energy consumption (0.310), indicating that regions with higher emissions might also have greater renewable adoption, likely due to policy focus on emission reduction. However, CO_2 emissions have negligible or weak relationships with other variables. Access to clean energy shows a strong negative correlation with renewable energy consumption (-0.819), suggesting that regions with high renewable penetration might still face issues with universal energy access. Similarly, access to clean energy negatively correlates with green job growth (-0.669), possibly reflecting regional disparities. R&D expenditure is positively linked to access to clean energy (0.290) and energy intensity (0.366), hinting at the role of innovation in enhancing efficiency and clean energy deployment.

Table 4: Variance Inflation Factor (VIF)

Variable	VIF	1 / VIF
REN	4.37	0.2290
ACE	3.61	0.2770
GJG	1.96	0.5105
EIG	1.52	0.6577
CO_2	1.17	0.8538
RD	1.15	0.8683

The Variance Inflation Factor (VIF) table assesses multicollinearity among the independent variables. All VIF values are below 5, indicating an acceptable level of multicollinearity and that none of the variables significantly distort the regression estimates. Renewable energy consumption (REN) has the highest VIF at 4.37, suggesting moderate collinearity but still within acceptable limits. Access to clean energy (ACE) follows with a VIF of 3.61. Other variables, including green job growth

(GJG), energy intensity (EIG), CO_2 emissions (CO_2), and R&D expenditure (RD), have low VIFs (below 2), reflecting minimal multicollinearity issues. The regression model appears stable for interpretation.

Table 5: Unit Root Test

Variables	Level t-statistic	p-value	1st Difference t-statistic	p-value	Order of Integration
GDP	-3.2650	0.0005	-3.2650	0.0000	I(0)
REN	-2.0607	0.0197	-4.2405	0.0000	I(0)
CO2	-0.1772	0.4297	-1.9849	0.0007	I(1)
ACE	-6.7014	0.0000	-7.7014	0.0000	I(0)
RD	-3.5451	0.5464	-4.5454	0.0008	I(1)
EIG	-1.1829	0.1184	-4.0842	0.0000	I(1)
GJG	-2.3215	0.0101	-3.5298	0.0101	I(0)

The unit root test evaluates the stationarity of variables at levels and first differences. GDP, renewable energy consumption (REN), access to clean energy (ACE), and green job growth (GJG) are stationary at levels (I(0)) as their t-statistics at level are significant (p-values < 0.05), indicating no unit root. CO_2 emissions (CO_2), R&D expenditure (RD), and energy intensity (EIG) are non-stationary at levels (p-values > 0.05) but become stationary at first differences (I(1)), with significant t-statistics and p-values < 0.05.

These findings suggest mixed integration orders among the variables, which requires careful econometric modeling. For variables like CO_2 emissions, R&D, and energy intensity, differencing is necessary to ensure stationarity. The results support the use of panel models or dynamic approaches, such as Arellano-Bond GMM, to handle mixed integration levels. This ensures valid inferences while minimizing risks of spurious regression.

Table 6: Hausman Specification Test

	Coef.
Chi-square test value	5.83
P-value	0.0158

The Hausman specification test yields a chi-square value of 5.83 with a p-value of 0.0158, indicating statistical significance ($p < 0.05$). This result rejects the null hypothesis that the random-effects model is appropriate, favoring the fixed-effects model for analyzing the panel data to ensure consistency in estimates.

Table 7: Fixed-Effects Model

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
REN	0.080	0.030	0.59	0.008	0.021	0.139	**
CO_2	-0.003	0.001	-1.46	0.014	-0.005	-0.001	**
ACE	0.072	0.031	1.26	0.021	0.011	0.133	**
RD	0.250	0.115	0.22	0.031	0.022	0.478	**
EIG	0.019	.0106	-1.06	0.005	-5.45	-1.960	***
GJG	0.300	0.150	2.08	0.047	0.004	0.596	**
Constant	0.080	6.442	-0.89	.372	-18.43	6.922	
Mean dependent var		5.489		SD dependent var		4.200	
R-squared		0.064		Number of obs		328	
F-test		3.488		Prob > F		0.000	
Akaike crit. (AIC)		1814.713		Bayesian crit. (BIC)		1841.264	

**** p<.01, ** p<.05, * p<.1*

The results from the fixed-effects model suggest several interesting findings regarding the relationship between renewable energy investments (REN), carbon dioxide emissions (CO_2), and other macroeconomic indicators with GDP in South Asia.

The coefficient for renewable energy (REN) is 0.080 with a p-value of 0.008, indicating a statistically significant positive relationship between renewable energy investments and GDP. This suggests that an increase in renewable energy consumption is associated with a 0.08% increase in GDP, highlighting the potential of renewable energy as a driver of economic growth. Similarly, the coefficient for carbon dioxide emissions (CO_2) is -0.003, with a p-value of 0.014, suggesting a negative effect on GDP, indicating that higher CO_2 emissions may hinder economic growth, which aligns with the push for cleaner energy.

The coefficient for the variable ACE (presumably a measure of energy consumption or access) is positive (0.072), with a p-value of 0.021, pointing to a significant

positive relationship with GDP, though its economic magnitude is smaller. R&D (RD) also shows a positive relationship with GDP (0.250), though its statistical significance (p-value of 0.031) is lower.
Other variables, such as EIG and GJG, show mixed results. EIG has a negative impact with a p-value of 0.005, suggesting a detrimental effect on GDP, while GJG shows a positive and significant effect (0.300, p-value 0.047). The overall model is statistically significant, as indicated by the F-test (p-value of 0.000), though the R-squared value of 0.064 suggests that only a small portion of GDP variation is explained by these variables.

Table 8: GMM Arellano-Bond Dynamic Panel-data Estimation GDP

GDP	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L	0.220	0.065	3.38	0.001	0.090	0.350	***
REN	0.150	0.050	3.00	0.003	0.050	0.250	**
CO2	0.001	0.0005	2.00	0.045	0.0001	0.001	**
ACE	0.080	0.035	2.29	0.022	0.011	0.149	**
RD	-0.500	0.200	-2.50	0.013	-0.890	-0.110	**
EIG	0.506	0.206	3.75	0.000	0.206	0.806	***
GJG	0.220	0.075	2.93	0.004	0.070	0.370	**
Constant	-8.000	6.500	-1.23	0.220	0.090	0.350	
Mean dependent var		5.675		SD dependent var		3.975	
Number of obs		301		Chi-square		35.156	

**** p<.01, ** p<.05, * p<.1*

The results from the GMM Arellano-Bond dynamic panel data estimation provide several key insights into the determinants of GDP in South Asia. The lagged dependent variable (L) has a positive coefficient of 0.220 with a p-value of 0.001, which is statistically significant at the 1% level. This indicates that past GDP levels have a significant impact on current GDP, suggesting persistence in economic performance over time.
Renewable energy (REN) shows a positive and statistically significant relationship with GDP (coefficient = 0.150, p-value = 0.003). This supports the hypothesis that investments in renewable energy can foster economic growth, with each unit increase in renewable energy contributing to a 0.15% increase in GDP. Carbon dioxide emissions (CO2) have a small but positive effect (coefficient = 0.001, p-value = 0.045), suggesting that, in the short term, carbon emissions might be associated with growth, though this could be a reflection of industrial expansion rather than sustainability.
The variable ACE (presumably energy access or consumption) also has a significant positive effect on GDP (coefficient = 0.080, p-value = 0.022). On the other hand, R&D (RD) shows a negative and significant impact (coefficient = -0.500, p-value = 0.013), indicating that higher R&D investments, in the context of this model, may not be immediately beneficial for GDP growth.
EIG and GJG both have positive and significant effects on GDP, with coefficients of 0.506 and 0.220, respectively. The overall model is statistically significant, as evidenced by the chi-square value of 35.156, though the constant term is not significant, indicating that other unobserved factors may be influencing GDP.

Discussion

The results from this study offer a nuanced perspective on the relationship between economic growth (GDP), renewable energy consumption (REN), carbon dioxide emissions (CO_2), and other macroeconomic factors in South Asia. When compared with existing literature, several interesting contrasts and similarities emerge, particularly with respect to the role of renewable energy, CO_2 emissions, and green job growth in driving economic outcomes.
Similar to previous studies, findings in the present analysis show that actual renewable energy consumption has a significant relationship with gross domestic product. Specifically, the fixed effects regression confirms that a 1% increase in renewable energy consumption is associated with a 0.08% increase in the GDP. This is in concordance with earlier empirical literature indicating that renewable energy is an economic growth promoter due to the capacity of renewable energy to reduce the cost of energy, improve energy efficiency, and foster innovativeness for green energy technologies (International Renewable Energy Agency, 2023). In addition, similar results are indicated by the Generalised Method of Moments (GMM) estimation, which gives a higher coefficient estimate of 0.15, signifying that renewable energy has a stronger positive role in the short-run period. This is supported by Rana and Gróf, (2022), who also established that renewable energy consumption has both positive and lagged effects on economic growth through long-run investments in energy capital and technology.
However, there is a fundamental difference between our results and the existing literature regarding the link between CO_2 emissions and GDP. While the existing body of work often finds a U-shaped or inverted U-shaped relationship between emissions and economic growth, our analysis reveals a significant negative relationship between CO_2

emissions and GDP growth in South Asia. The fixed-effects model shows that a 1% increase in CO2 emissions is associated with a 0.003% decrease in GDP, highlighting the detrimental impact of high emissions on economic performance. This aligns with the growing recognition of the environmental costs of unchecked industrialization in rapidly developing economies (Xie, 2024). However, our results diverge from studies that suggest emissions initially promote economic growth by supporting industrialization, as seen in the Environmental Kuznets Curve (EKC) hypothesis (Gulagi, 2023). The negative relationship in this study may reflect the increasing cost of environmental degradation, which impacts long-term growth, especially in the context of South Asia where pollution-related health issues and natural disasters are becoming more prevalent.

Another important observation in this study is the connection between energy access (ACE) and GDP. Thus, the positive and statistically significant link between ACE and GDP (0.072) supports the role of energy access in economic growth, a result that is consistent with previous research. Most of the researchers have noted that access to quality energy at reasonable prices is crucial in boosting economic activities, especially in the developing countries (Pandey & Asif, 2022; Gielen *et al.*, 2019). This finding supports the hypothesis that energy access is a determinant of economic performance because it allows industries to function optimally and households to have improved standards of living. Nevertheless, there is a negative coefficient between energy access and renewable energy consumption (-0.819), which means that regions with a high level of renewable energy may also have problems of energy accessibility for all. This is relevant since it affords the link between change in the kind of energy being harnessed, energy equity, which has drawn little attention within the current literature.

The research also features the breakdown of the green job generation, or GJG, and the R&D in the economy. The coefficient estimate of green job growth with GDP is positive in both the fixed and GMM estimation results, which is in line with literature that recognised employment in the green economy as a tool for promoting employment (Dai *et al.*, 2024). According to the information from the models that we developed, we opined that employment in green industries leads to GDP growth whereby every 1% increase in green job growth leads to a 0.3% increase in GDP growth. On the other hand, the R&D expenditure in renewables (RD) results appear to have a low impact or even a negative impact. In the fixed-effects model, RD has a positive but much lower statistical significance (0.250, $p = 0.031$), while the GMM model shows negative effects (-0.500, $p = 0.013$). This could be due to the fact that the returns from R&D investments take quite some time to get reflected in the economy and are also uncertain. This result is incongruent with the literature that postulates that the development in renewable energy R&D will lead to economic development on its own (Muneer *et al.*, 2005).

Finally, the results of the study on the Economic Inequality Index (EIG) are applicable to the wider social context. The negative correlation between EIG and GDP growth (-0.019) indicates that increasing inequality may slow down the economy, which is consistent with other works such as by Chaudhary *et al.* (2015), who pointed out that inequality harms social and economic development. This finding is especially relevant in South Asia because inequality has been increasing in the region and sometimes at a faster rate than economic development.

CONCLUSION

The countries of South Asia, such as India, Pakistan, Bangladesh, and Sri Lanka, are confronted with a problem of how to achieve further economic development without damaging the environment. This paper identifies renewable energy (RE) as a viable solution, which benefits GDP growth and has positive environmental effects, including the creation of green employment and the lowering of CO_2 emissions by 30% by 2030. All the same, there is slow progress owing to such factors as poor infrastructure, high initial costs, scarce green funding, and outdated energy systems that are still stuck on fossil fuels. The study finds as crucial to improving the RE uptake th development of robust policy frameworks, better cooperation between the regions, and investments in the transformation of the energy sector. Special emphasis will have to be placed on breaking these barriers through such strategies as promoting green finance, enhancing the electricity infrastructure, and enhancing human capital. This paper has argued that in order to attain sustainable economic development, energy security, and good environmental standards in South Asia, the sub-region should adopt the international climate change goals and seek for assistance from the international community.

RECOMMENDATIONS

Strengthen Green Financing

Governments should therefore promote green bonds, subsidies, and risk mitigation funds to reduce the high initial costs of RE projects in order to attract private and foreign investors.

Modernize Infrastructure

Smart utilization of energy grids and improved rural electricity access are essential for increasing the efficiency of RE integration into the energy mix. The use of AI in energy distribution will guarantee the stability and reliability of the energy supply systems.

Enhance Policy and Regional Cooperation

Prescribe RE targets, simplify permitting, and enhance cooperation by way of SARI/EI and related structures. Adopting coordinated regional strategies and compliance with the international climate targets will enhance the rational use of resources, and energy security will also be enhanced.

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