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Does Renewable Energy Matter to Achieve Sustainable Development Goals? The Impact of Renewable Energy Strategies on Sustainable Economic Growth

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The influences of renewable and conventional energy consumption on ecological sustainability remain unclear because of the dynamic economic and innovative framework. This investigation gives a new perception by exploring the association between the production of various sources of renewable energies (e.g., hydroelectric, wind, solar PV, geothermal, and biomass power) and economic growth encapsulating capital, government spending, and trade openness. This research used a heterogeneous approach for panel data and second generational tools for econometrics, which allow for cross-sectional reliance and slope heterogeneity. This study has revealed the substantial reason to back up the feedback assumptions between renewable energy sources and economic growth, using the Dumitrescu and Hurlin analysis. In terms of policy, this empirical analysis suggests enacting impactful policies that encourage green power and economic reform in an attempt to lessen CO2 concentrations in the biosphere.

Keywords: renewable energy sources, SDGs (sustainable development goals), economic growth, Asian economies, green power

1 INTRODUCTION

It is noted that growth and energy are positively linked. Economic growth increases the level of energy use, especially the need for fossil fuels. Renewable sources are environmentally friendly and low-carbon energy sources. Solar, wind, geothermal, and hydroelectric power do not produce greenhouse gases (GHGs). In recent years, many countries have adopted renewable energy technologies to protect the environment. Additionally, various factors, such as energy supply security, energy dependency, climate change, energy price volatility, health issues, and environmental disasters, encouraged the consumption of renewable energy sources by emerging economies. Economists, governments, policymakers, and researchers are now looking for methods to ensure a sustainable healthy environment (Chaabouni and Saidi, 2017; Akbar et al., 2020).

The discussions on the energy-growth-led Co2 emission nexus and the studies that supported the positive association between energy consumption and environmental quality are under consideration in this section. Numerous empirical studies include various important variables in the theoretical framework of the energy-growth induced emission. The study of tested the energy hypothesis, and results supported the presence of energy hypothesis. They further examined the growth-environment relationship, but the findings of their empirical analysis are not consistent. They used the cointegration techniques for Turkey, covering the time series data of 1968–2003; another period is 1992–2001. Their study tested the EKC hypothesis, and their findings indicated that Co2 emission is monotonic.

Examined the study for India and found a bidirectional association between energy consumption and GDP growth. However, they found two-way causality between Co2 emission and energy use. The study of for Bangladesh identified the causality floating from carbon emission to GDP growth and bidirectional causality found between economic growth and energy use. Explored the association between coal consumption, income, and environmental quality nexus for China and India. Their results show that the causal relationship between Co2 and income for China and causality moves from GDP growth to carbon emission. On the other side, two-way causality was found between coal consumption and the quality of the environment. The bidirectional causality was found between energy use (coal consumption) and the quality of the environment for India.

We divided the contributions of the present study into three distinct points. First, this research adds to the body of knowledge on the subject issue by investigating the effects of renewable energy sources, such as hydroelectric, solar photovoltaic, geothermal, biomass, and wind power, on economic growth in selected Asian nations from 1992 to 2018. Second, it demonstrates the relationship between the production of renewable energy sources and economic growth, along with conventional energy utilization, low trade barriers, and government spending regarding the selected Asian economies. The third contribution is that we used panel data rather than time-series data to establish the relationships between the above-mentioned factors as this approach reduces the issues relating to multicollinearity and provides much better estimates compared to time series data. Successively, the underlying connection of renewable energy, GDP (per capita), and energy dependence is investigated using an empirical approach. This study uses five different renewable energy sources (hydroelectric, wind, thermal, biomass, solar pv) and analyzed their effect on selected Asian economies. This study is different from the preliminary investigation to some extent. Particularly, the innovation of this research supervenes from investigating the consequences of renewable sources from the energy sources. The rest of the study is organized as follows: **Section 2** explores the literature; **Section 3** comprises methodology; **Section 4** deals with results and discussion; and the study conclusion is presented in **Section 5**.

2 LITERATURE REVIEW

The available literature highlighted the global outlook of the energy sector, which identified the demand and supply of energy, and geopolitical factors that change energy production in the long run. Examined and condemned the results of IEA for economic growth, technological advancement, and investment opportunities based on the projected outlook on new renewable energy. Since the last 20 years, the debate on energy production sources, healthcare, and CO2 emissions has become a much interesting topic in the economics literature for both developed and developing countries. Economists, governments, policymakers, and researchers are now looking for methods to ensure a sustainable healthy environment (Chaabouni & Saidi, 2017; Akbar et al., 2020; Liu et al., 2020). More energy requirement is expected due to urbanization, and it has increased the production of energy and the size of the market over the last few years. Compared to rural life, more energy consumption is required for urban life due to transportation, infrastructure development, sanitation, and construction of dams, bridges, roads, and houses. Numerous studies provided extensive literature on the development of the economic and depletion of renewable sources of energy (Alper and Oguz, 2016; Li et al., 2021; Liu et al., 2021; Nguyen et al., 2020; Yildirim et al., 2012; Shabbir and Wisdom 2020; Fang 2011).

Numerous other country-specific studies examined under the scheme of energy hypothesis (e.g., Shahbaz et al. (2013); Ahmad et al. (2017) for Croatia).

The environmental protection agencies also proposed more significant usage of renewable energy resources to offset the climate change rate (Apergis and Payne 2010; Jebli et al., 2016). The renewable energy sources' expenditure of OECD economies is nearly 85% of global spending on renewable energy, whereas the total population share is lower than 20%. This trend suggested that OECD economies have the largest healthcare expenditure globally (Blázquez-Fernández et al., 2019). Showed a strong, positive, and significant correlation between CO2 emissions and energy consumption. Gielen et al. (2019) pointed out the future of energy and suggested that, by the end of 2050, technologies associated with renewable energy resources and energy efficiency will be the leading indicators. Examined the relationship between energy consumption, economic growth, and CO2 emissions for the G7 countries. The results indicated positive connections between energy consumption, economic growth, and CO2 emission for G7 countries. Ernst et al. (2018) re-examined the social and economic approaches of energy drivers. The growth of the economy and income is the crucial driver for the economic approach, while life expectancy and population growth rate are the key drivers for the social approach. Social and economic factors play a significant role in developing the economy and help reshape the future of global energy.

3 METHODOLOGY

3.1 Data

This examination takes a panel data set regarding selected Asian economies (e.g., Bhutan, China, India, Singapore, Malaysia, Maldives, Pakistan, and Taiwan) for 1992–2018. The data are obtained from "Energy Information Administration" (EIA) and "World Development Indicators" (WDI) of the World Bank. The usage system of multi-variation consists of total national output per capita as a measure for sustainable economic growth (Chontanawat et al., 2008; Amri 2017; Huang et al., 2008; Jebli, and Youssef 2015; Koçak and Sarkgüne, si, 2017; Lin and Moubarak 2014; Sadorsky 2009).

3.2 Econometric Model Specification

The concept of this research is based on the functional form of the Cobb–Douglas (C-D) production model broadened by Kumar et al. (2014), Shahbaz et al. (2013), and Shahbaz (2012).

The output per capita is given as

$$Y_t = A_t K_t^{\varnothing}, \phi > 0. \tag{1}$$

Y_t represents GDP per capita, K indicates capital stock per capita, and A refers to technology. According to the model, technology can evolve, change, and be determined endogenously by energy, trade openness, and government spending. In addition, Ang (2008), Omri (2013) incorporated carbon dioxide emissions to analyze the impact of this factor on economic growth. Thus,

$$Y_t = \left[A_0 e g^T \left(Re\_h_t^{\alpha}\right)\left(Re_{-st}^{\rho}\right)\left(Re_{-wt}^{\ \sigma}\right)\left(Re_{-gt}^{\ \theta}\right) \times \left(Re_{-bt}^{\ \eta}\right)\left(Nre_t^{\vartheta}\right)\left(Gov_t^{\mu}\right)\left(TO_t^{\gamma}\right)\right]K_t^{\varnothing}, \tag{2}$$

where A_0 addresses the underlying supply of knowledge, Re denotes the renewable energy source, Nre indicates the non-renewable energy source, Gov means government spending, TO symbolizes trade openness, and t denotes time. When we convert **Eqs 2** to a linear form by applying the natural logarithm, we get

$$\begin{aligned} \text{In}(Y_t) = \lambda_{it} + \alpha \text{In}(\text{Re}\_h_t) + \rho \text{In}(\text{Re}\_\text{s}_t) + \sigma \text{In}(\text{Re}\_\text{w}_t) \\ + \theta \text{In}(\text{Re}\_\text{b}_t) + \vartheta \text{In}(\text{Nre}_t) + \mu \text{In}(\text{Gov}_t) + \gamma \text{In}(\text{TO}_t) \\ + \phi \text{In}(\text{K}_t) \end{aligned} \tag{3}$$

where $\lambda_{it} = \text{Ln}(A_0 e^{gT})$.

In **Equation 3**, t addresses time in the panel; i means the ith nation; λ represents a constant; α, ρ, σ, θ, η, ϑ, μ, γ, and ∅ individually indicate the elasticity coefficients of renewable energy sources in terms of hydropower $\text{In}(\text{Re}\_h_t)$, solar PV power $\ln(\text{Re}\_\text{s}_t)$, wind power $\ln(\text{Re}\_\text{w}_t)$, geothermal power $\ln(\text{Re}\_\text{g}_t)$, biomass power $\ln(\text{Re}\_\text{b}_t)$, non-renewable energy $\ln(\text{Nre}_t)$, government spending $\ln(\text{Gov}_t)$, trade openness $\ln(\text{TO}_t)$, and capital formation $\ln(\text{K}_t)$. This investigation divided the values of all indicators by the total population as a data preparation approach to convert them to per capita notation.

3.3 Empirical Findings and Discussions

In the first place, we investigated cross-sectional reliance in our panel data sets because it impacts the robustness of subsequent estimation findings if second-generational approaches are not used. In other words, when cross-sectional reliance occurs, we use second-generational methodologies of econometrics to obtain reliable long-run estimations.

To diagnose CD among nations in this investigation, we used a CD test (Pesaran, 2004). At the 1% level of significance ($p < 0.01$), the findings in **Table 1** present proof of cross-sectional reliance in our panel data. Then, we examined the homogeneity of a slope by employing the approach of Pesaran and Yamagata (2008).

Table 2 shows that the default hypothesis (H_0) of the homogeneous slope is not accepted at a 1% level of significance, implying that the existence of the slope heterogeneity is true. Evidence from **Tables 1**,**2** displays that traditional approaches such as LLC, IPS, and PP are not suited in this study because of cross-sectional reliance (Pesaran, 2007). As a result, we applied Pesaran's (2007) innovative unit root assessments for panel data sets, CIPS and CADF. **Table 3** shows that the default hypothesis (H_0) of unit root can be accepted at the level. However, it cannot be accepted at the first difference where the p-value is less than 1 percent, implying that the factors are only of order 1—I (1) variables.

We continued to discover their long-run association since all of our indicators are interconnected of order one. We used the cointegration analysis, which adopts the error correlation framework by Westerlund (2007).

Derived from the empirical outcomes in **Table 4**, this research continued to gauge the parameters in the long run. Grounded by the outcomes presented in **Tables 1**,**2**, we utilized the AMG assessor, which is unbiased and efficient and produces reliable estimates (Bond and Eberhardt, 2013). Furthermore, we incorporated the MG assessor of Pesaran and Smith's (1995) close by the CCEMG approach of Pesaran (2006). In terms of the diagnostic assessment, the outcome of the Pesaran CADF check with a minimum probability supports the not acceptance of the default hypothesis, so the residuals are stable or stationary. Additionally, when the root-mean-square error (RMSE) is low, the AMG appraiser has a good model fit. The default hypothesis of cross-sectional reliance is accepted. As a result, the error terms are cross-sectionally not dependent, confirming the method's reliability and robustness. The findings of the long-run assessment are shown in **Table 5**.

Table 5 shows that all the AMG assessor's coefficients are strongly significant, and all variables lnRe_h, lnRe_s, lnRe_b, lnTo, lnK, lnRe_w, lnRe_g, and lnGov have a positive effect on GDP per capita (lny), except for non-renewable energy (lnNre), as it shows significant negative impact on GDP per capita. In the long run, a 1% rise in non-renewable energy sources would reduce GDP by 0.13%, and a 1% rise in capital accumulation per capita boosts GDP by 0.139%, emphasizing the significance of capital for economic prosperity. This approach is consistent with an investigation revealed by Apergis and Payne (2010) for 13 Eurasia nations and for EU economies. Furthermore, the impact of a 1% increase in each renewable energy category, such as hydroelectric, solar PV, wind, geothermal, and biomass power, leads to a boost in GDP per capita by 0.14%, 0.39%, 0.12%, 0.03%, and 0.029%. In fact, the use of non-renewable and green energy adds significantly to the national output of the selected 45 emerging economies, according to AMG estimators' analysis of long-term impacts (Le and Sarkodie, 2020). Given the strong relationship between GDP and the expansion of power demand, the energy sector is critical to economic growth in general (Owusu and Asumadu, 2016). Our study exploration is consistent with that of Ewing et al. (2007), Bilgili et al. (2019), Bilgili et al. (2019), and Bulut and Inglesi-Lotz (2019), all of whom

TABLE 1 | Cross-sectional dependence analysis.

Variables	Coefficients	Corr.	*p*-value	Abs (corr.)
Lny	98.323***	0.69	0.00	0.89
ln(Re _*h*)	22.762***	0.41	0.00	0.46
ln(Re_s)	15.901***	0.29	0.00	0.31
ln(Re_w)	14.113***	0.38	0.00	0.45
ln(Re_g)	12.100***	0.34	0.00	0.42
ln(Re_b)	2.901***	0.22	0.00	0.24
ln(Nre)	26.067***	0.49	0.00	0.63
LnGov	54.677***	0.44	0.00	0.49
LnTO	27.133***	0.59	0.00	0.63
LnK	47.109***	0.57	0.00	0.68

Notes: p < 0.1, *p < 0.05, **p < 0.01, ***p < 0.001.

TABLE 2 | Heterogeneous panel analysis.

Variables	Δ_{adj} statistics	*p*-value	Δ statistic	*p*-value
Lny	98.224***	0.00	92.084***	0.00
ln(Re _*h*)	24.167***	0.00	20.691***	0.00
ln(Re_s)	27.771***	0.00	19.801***	0.00
ln(Re_w)	25.001***	0.00	17.819***	0.00
ln(Re_g)	23.100***	0.00	18.003***	0.00
ln(Re_b)	12.000***	0.00	9.709***	0.00
ln(Nre)	24.053***	0.00	25.536***	0.00
lnGov	143.099***	0.00	140.325***	0.00
lnTO	110.190***	0.00	107.316***	0.00
LnK	122.100***	0.00	120.039***	0.00

Notes: p < 0.1, *p < 0.05, **p < 0.01, ***p < 0.001.

TABLE 3 | The panel stationary properties' outcomes.

Variables	CIPS		CADF	
	Level	Δ	Level	Δ
Lny	−1.970	−3.5995***	−1.879	−3.551***
ln(Re_*h*)	−1.600	−4.190***	−1.603	−4.000***
ln(Re_s)	−1.599	−3.777***	−1.620	−3.501***
ln(Re_w)	−1.657	−4.018***	−1.524	−4.000***
ln(Re_g)	−1.590	−3.600***	−1.500	−3.845***
ln(Re_b)	−1.018	−2.799***	−1.010	−2.989***
ln(Nre)	−1.699	3.811***	−1.700	−3.900***
lnGov	−1.780	−4.535***	−1.765	−4.291***
lnTO	−1.400	−4.078***	−1.480	−4.580***
LnK	−1.099	−4.012***	−1.578	−4.302***

Notes: p < 0.1, *p < 0.05, **p < 0.01, ***p < 0.001.

reached similar conclusions. Our research hypothesis that renewable energy sources facilitate economic growth in selected Asian economies is confirmed by the long-run estimation (see **Table 5**). Furthermore, the influence of government spending per capita raises GDP per capita by 0.079%. Furthermore, while trade openness increases by 1%, the economy gains 0.030%.

The estimation's robustness is confirmed by the CCEMG and MG methodologies shown in **Table 5**. The explored coefficients are consistent and robust regarding their magnitudes and signs. We examined the interconnection among the indicators and evaluated the coefficients in the long run using the CCEMG,

TABLE 4 | Panel cointegration analysis.

Statistics	Value	*p*-value	*z*-value
G_τ	−5.790***	0.001	−6.389
G_α	−11.199***	0.000	−4.079
P_τ	−16.819***	0.002	−2.002
P_α	−9.018***	0.000	−1.709

AMG, and MG estimators to give comprehensive guidelines for policy suggestions. However, above tables show a feedback framework for renewable energy use by type, GDP, capital accumulation, government spending, and trade openness. Furthermore, the connection analysis supports our research objective, which states that conventional energy use, productivity growth, carbon intensity, and renewable energy sources (wind, solar, hydroelectric, geothermal, and biomass) impact one another.

4 EMPIRICAL FINDINGS AND DISCUSSION

The findings of this study have important consequences for the energy policies of selected Asian countries, both private and public sectors, because they aid in identifying the industrial sectors that contribute the most to the economy and have the most long-term energy requirements. However, because of their low cost and low-carbon emissions, renewable energy sources, such as hydroelectric, solar PV, geothermal, wind, and biomass power, are among the major drivers of economic progress in Asian countries.

Finally, the results help corporations predict consumer behavior in the long run. Such changes in demand can be incorporated into power supply companies' capital budgeting components for strategic decision-making and future policy judgments.

The findings of our study are similar to several studies, such as Ewing et al. (2007), Tugcu (2018), Arif et al. (2020), Li et al. (2021), Arasu et al. (2021), Muhammad et al. (2020), Yikun et al. (2021), Jun et al. (2021), Khan et al. (2021), Bilgili et al. (2019), and Bulut and Inglesi-Lotz (2019). Moreover, conducted a study regarding bioenergy and economic growth from G7 countries with similar results. Examined the relationship between environmental pollution and hydropower through panel data among selected OECD economies. Studied renewable energy consumption-growth nexus in Central America. Chien and Hu (2007) explored the renewable energy and macroeconomic efficiency of OECD and non-OECD economies. Kahia et al. (2017) investigated renewable and non-renewable energy use toward economic growth nexus from MENA net oil-importing countries. Koçak and Sarkgüne, si, (2017) studied renewable energy and economic growth nexus in the black sea and Balkan countries. Lin and Moubarak (2014) studied renewable energy consumption and economic growth nexus from China.

However, Shahbaz et al. (2015) investigated whether renewable energy consumption adds to economic growth using an application of the autoregressive distributed lag model in Pakistan. The findings of their study are partially associated with our study in the context of the Pakistan

TABLE 5 | Long-run empirical estimation.

Regressors	CCEMG estimator		MG estimator			AMG estimator	
	Coef. t-stat	*p*-value	Coef.	t-stat	*p*-value	Coef. t-stat	*p*-value
ln *Re-h*	0.146*** 9.14	0.002	0.129***	6.08	0.002	0.140*** 8.56	0.001
ln *Re-s*	0.041*** 2.59	0.003	0.049***	2.80	0.002	0.039*** 3.19	0.000
ln *Re-w*	0.127*** 5.61	0.001	0.128***	6.10	0.001	0.121*** 6.10	0.002
ln *Re-g*	0.045** 1.77	0.029	0.035**	2.08	0.032	0.03** 2.12	0.040
ln Re-b	0.021* 1.79	0.050	0.011*	2.11	0.062	0.029* 2.00	0.079
ln Nre	−0.139*** 8.79	0.002	−0.141***	7.87	0.001	−0.131*** 7.90	0.002
ln *Gov*	0.108*** 5.30	0.001	0.090***	4.90	0.008	0.091*** 4.98	0.001
ln *TO*	0.030** 2.20	0.031	0.040***	2.90	0.005	0.041** 2.10	0.031
Ln K	0.131*** 9.10	0.002	0.132***	6.29	0.002	0.139*** 8.07	0.003
CD-test	1.307	0.272	0.390		0.679	0.214	0.779
Diagnostic							
I(0)	[0.000]	—	[0.000]	—	—	[0.000]	—
RMSE	0.0187	—	0.0198	—	—	0.0170	—

Notes: p < *0.1,* *p < *0.05,* **p < *0.01,* ***p < *0.00; I (0) represents* p-values *for CADF, analysis with* H_0*: non-stationarity; RMSE, root-mean-squared error.*

economy. Examined the energy security and renewable energy policy analysis of Pakistan. Their renewable energy findings have the same effect described in our study in detail. Moreover, study "Is it Wise to Compromise Renewable Energy Future for the Sake of Expediency? An Analysis of Pakistan's Long-Term Electricity Generation Pathways" only consists of electrical energy as a source of renewable energy in the context of Pakistan, and our study also takes electrical energy as a source of renewable energy with similar results of both studies. The findings of study are moderately associated with our study as he used trade openness with the relationship towards renewable energy.

5 CONCLUSION

This study investigates the association between various renewable energy sources and economic growth in selected Asian nations. It uses the panel data set of "selected Asian countries" for the period 1992—2020, from "World Development Indicators" (WDI) of World Bank and indicators from "Energy Information Administration" (EIA). We utilized the second-generation panel data econometric procedures that produce reliable appraisals in heterogeneous data sets. In the wake of identifying all I (1) factors utilizing CIPS and CADF unit root analysis, we examined the association in the long run by utilizing Westerlund panel cointegration analysis (see **Table 5** for details).

The outcomes of this study confirm the significant positive impact of renewable energy sources, such as hydroelectric, solar PV, wind, geothermal, and biomass power, on economic growth. Renewable energy consumption offers Asian economies a twofold benefit: reducing CO_2 emanations and advancing economic growth. The gradual level of environmentally friendly power sources can supplant old ones and meet the growing need for energy. That will allow Asian economies to concentrate on economic progress without worrying about carbon footprint or environmental threats. What is more, the entrance of renewables in the energy blend permits Asian economies to accomplish SDGs goals.

We suggest that institutional quality be improved throughout the Asian region to achieve the advantages of ecological sustainability and stability in the economy. Furthermore, the empirical findings demonstrate that adaptable fiscal measures to regulate the circular economy and optimal trade-led development strategies are critical. Appropriately, the Asian region should make capital easier to allocate efficiently, stimulate foreign investment specifically in the export market, and incentivize investment inflows in green power and transformative technology, all of which add to sustainable and green growth. Three leading variables are used for research, but these variables are not fully utilized.

AUTHOR CONTRIBUTIONS

All authors work equally in this paper.

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