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REVIEW

Do Energy Resources matter for Growth Level? The dynamic effects of different strategies of renewable energy, carbon emissions on sustainable economic growth

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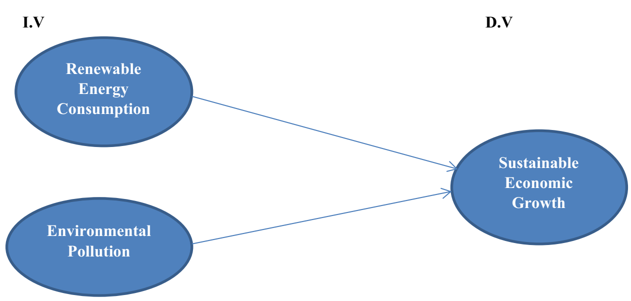
Abstract
This study examines the association between renewable energy strategies and carbon emissions on sustainable economic growth under affordable and clean energy sources to achieve sustainable development goal seven. This research provides new insight by exploring the nexus between environmental pollution and the creation of numerous bases of renewable energies, such as hydropower, wind power, biomass, geothermal, and solar photovoltaic, and economic growth epitomizing capital, trade openness, and government spending. Moreover, this investigation uses second-generation devices for econometric investigation and a heterogeneous methodology for panel data for selected Asian countries. The empirical exploration of long-term influences drove by the Common Correlated Effects Mean Group, close by Augmented Mean Group and Mean Group assessors confirm the positive and significant influence of renewable energy like hydropower, solar photovoltaic, wind, biomass, and geothermal on the economic growth of Asian economies. Study findings provide valuable insights for all stakeholders in an integrated and coherent manner.

Graphical abstract



Keywords Renewable energy sources · Environment pollution · Economic growth · Solar photovoltaic · Asian economies · Green energy

JEL Classification D11 · E12

Introduction

The absence of a causal relationship between growth and energy or neutrality hypothesis stated that both energy and growth do not cause each other. Therefore, economic growth is not depressed by the policies based on conservation energy. The past empirical works supported the evidence of

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the neutrality hypothesis, especially in the context of Sub-Saharan African (low and upper-middle-income) economies. Recently, North American (high-income) countries and European (upper middle-income) economies also supported the absence of a causal association between energy and growth relationship. Huang et al. (2008) confirmed the evidence of the neutrality hypothesis for 73 nations using panel data-based dynamic estimation and found that low-income countries could not support the causal connection between energy and growth.

Countries are, in fact, unable to cut environmental emissions while also increasing their incomes. To put it another way, continued economic growth necessitates increased energy consumption, which results in increased carbon emissions (Bai et al. 2022a, b Zeng et al. 2022; Zheng et al. 2022; Hayat et al. 2022a, b; Malik 2014; Ge 2022). Many agree that renewable/green energy sources will help to rebalance environmental quality and economic development (Ali et al. 2022; Azam et al. 2021; Liang et al. 2022; Nawaz et al. 2022a, b, c; Hayat et al. 2022a, b; and Nawaz et al. 2022a, b, c). Therefore, the green energy sector is now attracting more and more attention from governments, businesses, and academics in different countries and regions, which can be due to several factors. Lately, oil prices have been fluctuating, and energy security has been questioned (Al Rousan et al. 2018).

Although there is much discussion in the literature about the association between renewable energy sources, non-renewable energy sources, trade openness, and economic growth, the findings are still inconclusive. Since the estimation methods used are not based on an adequate quantitative system, most studies are criticized for the validity of the measured coefficients and elasticities. Previous studies used estimation techniques such as FMOLS, 2SLS, and GMM, which neglect cross-sectional dependence and slope heterogeneity, essential for unbiased and robust results. Hence, our research contributes to the current literature by using the latest panel data technique (AMG estimator) that allows CSD and slope heterogeneity to evaluate the heterogeneous effects of non-renewable sources of energy and renewable energy sources on the economic growth of thirteen Asian economies.

The rest of the paper is organized as follows: Sect. 2 explores the literature review; Sect. 3 examines methodology; Sect. 4 uncovers empirical findings and their discussion and finally Sect. 5 wrap up the conclusion.

Literature review

Numerous studies provide extensive literature on the development of the economy and depletion of renewable sources of energy (Liu et al. 2021, Nguyen et al. 2020; Shabbir and Wisdom 2020; and Li et al. 2021; Nawaz et al. 2021e, a, b, c, d; Zehra et al. 2022; Shabbir and Zeb 2020). The analysis of Ozturk et al. (2010) discussed the conservation hypothesis for low-income economies and confirmed the evidence of the conservation hypothesis in the long run time period. The unidirectional causality is floating from growth to energy use in this conservation hypothesis. Consequently, economic growth cannot be depressed if the government adopts stringent energy policies. This indicates that energy management policies are effective in the economy, and the country's economic growth may not be hampered. Supported the presence of this conservation hypothesis and explained that if there are changes (increase) occur in economic growth, it may lead the changes (increase) in the use of energy in the same direction.

Moreover, Huang et al. (2008) used panel techniques to examine the nexus between growth and energy. Moreover, Nawaz et al. (2021a; b, c, d, e), Shabbir (2020a; b), Ozturk (2010), and Nawaz et al. (2022a; b, c) categorized the energy-growth nexus into four parts that show the direction of causality between energy and growth and comprehensively contribute to policy making. In the Kenyan population, it is found that the standard of living is adversely affected by energy poverty (Liu et al. 2022a, b, c; Shabbir 2022; Shabbir and Zeb 2020; Nawaz et al. 2021a, b, c, d, e). Whereas, explored the spatio-temporal dynamics of multidimensional energy poverty and identified causing and reducing factors of energy poverty in China. They used the panel vector autoregressive (PVAR) model and used exploratory spatial–temporal data analysis (ESTDA) from 2007 to 2017 at the provincial level.

Investigated how energy poverty and economic development are correlated in South Asian economies. They used Panelized Quantile Regression (PQR), Autoregressive Distributed Lag (ARDL), and Panel integration to demonstrate the short- and long-run associations. The estimates revealed the negative impact of energy poverty on the growth rate. Measured the energy poverty in Lao PDR and investigated how it affected the health status and average years of schooling. Bai et al. (2022a, b) describes the biogass transplantation for environment protection. Muhammad et al. (2021) explored the nexus between willingness to pay for renewable energy sources from Turkey. Mughal et al. (2022) examined the causal relationship among energy consumption, CO_2 emissions, and economic growth through technology innovation as the moderate variable. The findings of this study indicate that energy consumption and economic growth have a positive association, while technology innovation plays an effective role in all the variables. Estimated that agricultural productivity, effective utilization of labor, and improving income by using different livelihood activities would cause compress multidimensional energy poverty. Regressed that higher education in Nigeria is the strongest determinant to combat multidimensional energy poverty.

Methodology

Description of data

This research uses a set of panel data concerning selected Asian countries such as (India, China, Indonesia, Japan, Pakistan, Maldives, Malaysia, Philippines, Singapore, Thailand, Vietnam, Turkey and Taiwan) for the period 2006–2021. The data is gathered from "Energy Information Administration" (EIA) and 'World Development Indicators" (WDI). However, CO_2 is used as a proxy for environmental pollution in this study. The study uses Panel data because it helps to observe time entities. In addition, panel data analysis has empowered researchers to embrace longitudinal investigations in a wide diversity of fields.

Description of econometric model

The idea behind this study is derived from the functional version of the Cobb–Douglas (C–D) Production methodology expanded by Shahbaz (2012), Kumar et al. (2014), and Shahbaz et al. (2013).

The yield per capita is presented as:

$$Y_t = A_t K_t^{\emptyset},\ \emptyset > 0 \quad (1)$$

The abbreviations in (1) are as follows: y_t denotes for GDP per capita, A for technology, and k for capital stock per capita. Thus:

$$Y_t = \left(A_0 e^{gT} R\_h_t^{\alpha} \mathrm{Re}\_s_t^{\rho} \mathrm{Re}\_w_t^{\sigma} \mathrm{Re}\_g_t^{\theta} \mathrm{Re}\_b_t^{\eta} \mathrm{Nre}_t^{\vartheta} \mathrm{Gov}_t^{\mu} \mathrm{To}_t^{\gamma} \mathrm{CO2}_t^{\gamma}\right) K_t^{\emptyset} \quad (2)$$

where "A_0" is the fundamental supply of knowledge, "Re" stands for a renewable source of energy, "Nre" means non-renewable sources of energy, "Gov" stands for government expenditure, "TO" is trade openness, "t" indicates time. The result of converting Eq. (2) to a linear form is:

$$\begin{aligned} \ln(Y_{ti}) &= \lambda_{it} + \alpha \ln(\mathrm{Re}\_h_{ti}) + \rho \ln\left(\mathrm{Re}\_s_{ti}\right) \\ &+ \sigma \ln\left(\mathrm{Re}\_w_{ti}\right) + \theta \ln\left(\mathrm{Re}\_g_{ti}\right) \\ &+ \eta \ln\left(\mathrm{Re}\_b_{ti}\right) + \vartheta \ln\left(\mathrm{Nre}_{ti}\right) \\ &+ \mu \ln(\mathrm{Gov}_{ti}) + \gamma \ln(\mathrm{TO}_t i) \\ &+ \gamma \ln(\mathrm{CO2}_t i) + \emptyset \ln(K_{ti}) \end{aligned} \quad (3)$$

In the above Eq. (3), "I" stands for the ith nation; λ signifies the constant; $\emptyset$, ρ, γ, σ, μ, ϑ, α, η and θ independently address the elasticity of factors of Renewable sources of energy such as solar pv $\ln(\mathrm{Re}\_s_t)$, hydropower $\ln(\mathrm{Re}\_h_t)$, wind power energy $\ln(\mathrm{Re}\_w_t)$, biomass $\ln(\mathrm{Re}\_b_t)$, geothermal $\ln(\mathrm{Re}\_g_t)$ non-renewable energy $\ln(\mathrm{Nre}_t)$, ln (TO_t)Tradeopenness, Government spending $\ln(\mathrm{Gov}_t)$, Capital formation $\ln(K_t)$, environment pollution ln $(\mathrm{CO2}_t)$.

Econometric approach

Exploration with panel data set investigation necessitates a thorough examination of the implications of specific "unobserved common processes" or ("factors") on both the residual sides as well as among variables. To avoid biased and untrustworthy evaluation when the panel data set is heterogeneous and experiences significant cross-sectional dependency, we implemented second-generation techniques of econometrics (Breitung 2005; Liu et al. 2022a, b, c, Pesaran 2004; and Phillips and Sul (2003)).

Empirical findings and discussions

We first looked into cross-sectional reliance in our statistics since it affects the robustness of following estimation conclusions if second-generational techniques are not applied. When cross-sectional dependence happens, we utilize second-generational econometrics procedures to acquire accurate long-run assessments.

The H_0 (default hypothesis) of the homogeneous slope is not accepted at a 1% level of significance, implying that the existence of the slope heterogeneity is true (Table 2). Evidence from Tables 1, 2 and demonstrates that traditional approaches like LLC, IPS, and PP are not appropriate for this research due to cross-sectional dependence (Pesaran 2007). Accordingly, we employed Pesaran's (2007) advanced unit root calculations for panel data, CADF, and CIPS.

We kept on exploring their long-run association since our pointers are all interrelated of orders one. We employed the cointegration investigation, which embraces the error connection paradigm by Westerlund (2007) as mentioned in below (Table 3).

This study carried out long-run parameter gauging based on the empirical findings in Table 4. Based on the results shown in Tables 1, 2, we adopted the AMG inspector (Eberhardt and Bond (2009), which generates accurate estimates, is unbiased, and is productive.

Table 5 illustrates that all of the AMG accessor's coefficients are strongly significant, and all of the variables lnRe_h, lnRe_s, lnRe_b, lnTo, lnCo2 lnK, lnRe_w, lnRe_g, and lnGov have a positive effect on GDP per capita (lnY), except non-renewable energy (lnNre) as it shows negative and significant impact on GDP per capita. Also, the impact of a 1% increase in each renewable energy type like solar PV, hydropower, wind, biomass, and geothermal, tends to a enhancement in GDP per capita by 0.39%, 0.14%, 0.12%, 0.029, and 0.03%, percent.

Table 1 Analysis for cross-sectional dependence

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
LnCO2	22.873***	0.54	0.00	0.54
LnK	47.109***	0.57	0.00	0.68

*$p<0.1$, **$p<0.05$, ***$p<0.01$

Table 2 Analysis for heterogeneous panel

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
LnCO2	114.120***	0.00	109.376***	0.00
LnK	122.100***	0.00	120.039***	0.00

*$p<0.1$, **$p<0.05$, ***$p<0.01$

The exploration's robustness is acknowledged by the CCEMG, and MG methodologies revealed in Table 5. However, Table 5 discloses that there is a feedback mechanism in place for renewable power use by category, Capital accumulation, GDP, Government spending, and Trade Openness. It is observed that the results of this paper are comparable with many other studies, for instance; Ewing et al. (2007), Liu et al (2022a, b, c), Yaqoob et al (2022), Wang et al (2022), Wen et al (2022), Shabbir et al. (2020a, b); Arif et al. (2020), Cao et al (2022), Chen et al (2022), Dai et al (2022), Yikun et al. (2021); Jun et al. (2021); Li et al. (2021), Arasu et al. (2021); Muhammad et al. (2021); Khan et al. (2021); Bilgili et al. (2019), and Bulut and Iglesi-Lotz (2019).

Table 3 Outcomes of panel's stationary properties

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***
LnCO2	−1.360	−4.463***	−1.130	−4.190***
LnK	−1.099	−4.012***	−1.578	−4.302***

*$p<0.1$, **$p<0.05$, ***$p<0.01$

Table 4 Analysis for panel cointegration

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

Discussion and conclusions

This research investigates the causal relationship between numerous renewable energy sources and economic growth in chosen Asian nations for the period 2006–2021. We employed second-generation econometric procedures for panel data that give reliable evaluations in heterogeneous statistics. In the wake of identifying all $I(1)$ elements utilizing CADF and CIPS unit root exploration, we inspected the link in the long-run by employing the Westerlund Panel cointegration assessment (see: Table 5).

The empirical findings of this exploration reveal the positive and significant influence of renewable energy like hydropower, solar PV, biomass, geothermal, and wind on economic growth. As a result, Asian nations will be able to focus on their economic progress without being concerned about their environmental dangers or carbon footprint. Additionally, the addition of renewable energy sources to the energy mix enables Asian nations to achieve SDGs' objectives.

More specifically, the study proposes that institutional competence be raised across the Asian continent. Also, Asian countries should facilitate the effective allocation of capital and encourage investment in transformative technologies and in green energy, each of which contributes

Table 5 Empirical estimation in the long-run

Regressors	CCEMG estimator			MGestimator			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_*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 Re_*w*	0.127***	5.61	0.001	0.128***	6.10	0.001	0.121***	6.10	0.002
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 TO	0.026**	2.13	0.025	0.035***	2.80	0.004	0.031**	2.45	0.021
Ln K CD-test	0.131***		0.002	0.132***	6.29	0.002	0.139***		0.003
	9.10		0.272	0.390		0.679	8.07		0.779
	1.307						0.214		
Diagnostic									
RMSE	0.0187			0.0198			0.0170		
I(0)	[0.00]			[0.00]			[0.00]		

Root Mean Squared Error is denoted as RMSE as well as *I*(0) stands *p* values for CADF assessment with H_0: non-stationarity; RMSE signifies Root Mean Squared Error

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

to sustainable growth. Furthermore, this study can further be explored by expanding the panel of countries selected in their research. Finally, future researchers may use cross sectional data to better understand the real facts and figures regarding selected sample.

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Data availability Enquiries about data availability should be directed to the corrsponding author only.

Declarations

Conflict of interest The authors have not disclosed any competing interests.

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