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REVIEW ARTICLE

The dynamic impact of renewable energy sources on environmental economic growth: evidence from selected Asian economies

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Abstract

The linkage between renewable energy resources and environmental influences on economic growth among selected Asian economies play a vital role in sustainable economic development. This study encompasses the panel data sets for eight selected Asian countries, and the period starts from 1990 to 2018. This research relies on the panel vector error correction model (PVECM) for data estimation. The overall findings indicate that biomass, geothermal, and wind power sources of energy have a positive and significant impact on the economic advancement of Asian economies. Besides that, as opposed to the other two renewable energy sources, windpower has a greater impact on economic development. Furthermore, the empirical findings of current research have significant implications towards selected Asian countries' energy policy related to both private and public sector enterprises as it helps in identifying the industrial sectors which have greater contribution towards the economy and their energy requirements in long term.

Keywords Asian economies · Sustainable economic development · Renewable energy source · PVECM · Environmental sector

JEL Classification E14 · C11

Introduction

The supply of renewable energy, either in terms of electricity or thermal power, and building retrofits are crucial steps for reducing environmental consequences in line with the European Union's new decarbonization goal. On the other

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hand, the predicted benefits are not limited to a reduction in energy demand and mitigation of environmental repercussions. Besides that, consumers may experience add up over time at the construction site (like as improved interior comfort), as well as at the societal level (including wellbeing impacts, job creation, contribution to global warming, and improved energy security) (Dell'Anna 2020; Berto et al. 2020).

Renewable power sources are significant basis of economic prosperity. In contemporary occasions, the populace is expanding global enormously, and therefore, the interest for the creation of energy from expendable ordinary resources has expanded. Subsequently, energy value and environmental concerns rise to imperil the sustainability of the developing economy. Oppositely, renewable energy is shaped after topped off natural resources to upgrade energy security and obliging the issues of environmental change and a worldwide temperature alteration. Renewable energy implies a fundamental component for achieving continuous economic advancement (sebri and ben-salha 2014).

According to the International Energy Agency (IEA) (2020), renewable energy accounted for an estimated 28% of worldwide electricity production in Quarter 1 2020, up from 26% in Quarter 1 2019. The gain in renewables came primarily at the expense of gas and coal, despite the fact that those two categories still account for about 60% of worldwide electricity generation. Furthermore, renewable power generation climbed by nearly 3%, owing to new solar PV and wind projects that were installed in the previous year, as well as the fact that renewables are typically scheduled before different sources of energy. Electrical grids have enabled to accommodate increased shares of solar PV and wind in addition to dispirited electricity demand. In Q1 2020, the usage of renewable power in terms of biofuels decreased as the use of mixed fuels for road traffic decreased. Accordingly, the global consumption of renewable energy increased by roughly 1%. The global consumption of renewable power was 1.5% greater in Quarter 1 2020 than it was in Quarter 1 2019. The increment was fuelled by an ascent of about 3% in renewable power sources after in excess of 60 GW of wind-based power projects and 100 GW of solar-based power projects were finished in 2019.

In line with the global trend, Asian economies like Bangladesh, Sri Lanka, Pakistan, Nepal, and India are seeing an increase in consumer demand for energy as a result of numerous development programs and population expansion (Abbas et al. (2018); Shukla et al. 2017). Due to a considerable imbalance between the capability of fossil fuel provision and the energy consumption in the majority of Asian economies, there is an energy demand shortfall (Conte and Monno 2012). This is a significant impediment to achieving the numerous socio-economic sustainable development goals set by the region's governments. Balakrishnan et al. (2020) explore the capacity of renewable power installed in emerging economies by mainly focus on the Chinese economy. The research reveals that with the help of private sector investments, renewable sources of energy supply can be facilitated. This is an extraordinary hindrance to accomplish the diverse socio-economic advancement goals set by the respective state governments of the locale. Thusly, for fulfilling the expanded energy need and lessening the greenhouse gas emanations, environmentally friendly power is the irreplaceable decision for the emerging economies, as a significant number of this energy, like solar and wind energy, will keep going forever (Shukla et al. 2017). Given the significance and prosperity of environmentally friendly power, understand the unique association between economic growth and renewable energy sources of energy consumption for adding to the empirical literature of sustainable energy future and energy economics. Hence, this investigation means to determine this issue which is as yet an under-explored area.

The oddity of this exploration clarifies the impacts of renewable energy sources, by aggregate or type, on growth of selected Asian economies: Bangladesh, China, India, Indonesia, Malaysia, Nepal, Pakistan, and Sri Lanka, starts from 1990 to 2018. Progressively, the hidden association between energy dependence, GDP (per capita), and renewable energy is explored by empirical testing. This inspection examines five unique fonts of renewable energy and their impact on Asian economies, and it is not the same as the fundamental examinations somewhat. Specifically, the development of this approach happens from researching the outcomes of renewable sources. Secondly, the study demonstrates the causal association between energy dependence, economic growth, and renewable energy production, in terms of capital formation, renewable energy consumption, and the labour force of Asian economies.

Third, our exploration adds to the current body of empirical literature on the given topic by exploring the relationship of the utilization of environmentally friendly power, i.e., renewable energy, in the type of hydroelectricity and its effect on economic enlargement. The significance of this topic likewise becomes visible when we consider the way that the eight nations were picked for the motivation behind this examination for certain nations positioning as top toxins, and thinking about the negligible effect of hydroelectricity on the climate.

The current examination is adding to a restricted arrangement of studies comprising just of two earlier investigations: first by Omay and Kan (2010) and second by who had prior utilized the method of "nonlinear panel smooth transition vector error-correction model" to evaluate the effect of power utilization on the enlargement of the economy. Omay and Kan (2010) investigated the utilization of absolute electricity, whereas utilized the complete utilization of renewable power for their examination. With the end goal of this investigation, we basically centre on the utilization of hydroelectricity as the past explorations appear to do not have this perspective, and yet we utilize a similar strategy i.e., “nonlinear panel smooth change vector error correction model” for our estimation as supported by our study literature review.

Fourth, it identifies with the truth that we have utilized panel data as opposed to time-series data to set up the causal associations between the previously mentioned factors as this methodology lessens the issues identifying with multicollinearity as well as gives much better gauges when contrasted with time-series data. This study uses five distinct sources of renewable energy for instance: hydropower, wind, thermal, biomass and solar PV, and their effect on Asian economies. Furthermore, the rest of the empirical study is summarized as follows: “Literature review” covers previous literature; “Methodology” highlights methodology; “Results and discussions” demonstrates results and their discussion, and finally conclusion is presented by “Discussion and conclusion.”

Literature review

The association between energy use and GDP growth have been discussed by various researchers with different econometric techniques within different time span. The VECM and co-integration technique of Johansen-Juselius/causality tests of Engle-Granger/Sims are used usually in different studies. Many researchers for instance investigated the draw backs of conventional/traditional causality tests because it heavily depends on the process of time-dependent like the process of adjustment of stock. Furthermore, explained that the future economic growth cannot be determinant/cause by present use of energy.

The energy significantly boosts the level of economic growth according to the energy-led growth hypothesis, and energy reduction policies effectively depressed the level of economic growth. This relationship is also called unidirectional association between energy and growth; therefore, the energy acts as the complement of the other inputs (capital and labour) and imperative ingredient of the production process. In the recent existing literature, this relationship is well studied in the context of upper, high-income group that supports this hypothesis; in short-run time span, it is supported by lower-middle-income groups and supported in least developing countries for the long-run time period. Also tested this hypothesis in the context of selected countries of Gulf Cooperation Council (high-income) by using the test of Pedroni co-integration and confirmed this hypothesis. The conservation hypothesis is confirmed by few empirical studies for developing economies. Supported the existence of conservation hypothesis for 18 developing nations. The statistical results of generalized moment method (GMM) and variance of autoregressive method (VAR) techniques fully support the evidence of this hypothesis in these developing countries.

Huang et al. (2008) have used the data of seventy three countries and supported this hypothesis, and found the unidirectional relationship between economic growth and energy. They examined the conservation hypothesis for middle-income nations using panel dynamic estimation method and confirmed the presence of this hypothesis. Supported the presence of conservative hypothesis for selected countries of Western European by using the method of Granger causality and co-integration tests. Also used the panel co-integration and causality test and supported the evidence of energy-growth conversation hypothesis. Used Granger causality and co-integration tests for seven countries of Central America and confirmed the energy-led growth hypothesis or energy significantly causes the economic growth in lower-middle-income economies of Central American. The study of Ozturk et al. (2010) confirmed the evidence of energy-led growth hypothesis for the lower-income-based economies using the Granger causality test. Similarly, Obtained the data of 93 countries and found mixed results i.e., energy-led growth hypothesis confirmed for Africa, Latin America, Asia, G6, and Western Europe countries, and different results of global panel data can be seen. Supported the evidence of energy-led growth hypothesis by using panel Granger causality and co-integration tests for the panel of West African countries.

Furthermore, the panel and country-specific data has discussed the energy-growth hypotheses; for this purpose, discussed it for USA and Malaysia respectively; for Turkey, the analysis of examined this hypothesis; for Tunisia, and examined this hypothesis; for discussed it; for South American countries, data is used by Apergis and Payne (2010); for Malaysia, examined this relationship; for Indonesia, Singapore, Malaysia, Thailand, and Philippines, the analysis of Chiou-Wei et al. discussed this relationship; for Pakistan, evaluated the energy-growth hypothesis; for the selected Asian countries discussed by Nguyen et al. 2020; Arasu et al. (2021); Kumari et al. (2021); Anser et al. (2021a, b, c); Shabbir and Wisdom (2020); Ehsan et al. (2021); Shabbir (2020a, 2020b); Sadiq et al. (2021); for and the studies based on Vietnam examined by and.

The energy and GDP growth have complementary relationship. The bidirectional association between growth and energy indicates that economic growth significantly causes the use of energy and increases the level of energy use that boosts the level of GDP growth. The efficient utilization of energy-based policies may significantly increases the level of economic activities, and effective economic growth policies may boost the level of energy use. Recently, the evidence of feedback hypothesis confirmed for various developed (OECD) nations.

According to, the small sample size prosperities of cointegration and traditional unit root tests also criticized by various researchers. introduced ARDL method to overcome these limitations; this test does not need any unit root tests. examined that the results of the different studies are inconclusive because of different sample size of the data, types of data different types of econometric methodologies and specifications, the selection of countries, and different factors endowment.

However, in addition, Ozturk (2010) explained that the findings of the all these studies provide inconclusive results while examine the GDP growth and energy use relationship. The difference of the studies can be seen in terms of short- and long-run analyses as well as the direction of causality also diverse in different countries. In addition, the analysis of evaluated the energy-led economic growth relationship and found that energy and growth have bidirectional relationship in the context of 25 OECD countries over the period of 1981–2007. The management policies of energy and variation in climatic conditions in different countries also provide different results. The energy-led growth hypothesis is evaluated by three significant models namely, demand based energy models, energy bivariate models, and multivatiate. Shabbir et al. (2020a, b), Liu et al. (2021), Arif et al. (2020), Yu et al. (2020), Fatai et al. (2004), and discussed about the demand models. Chontanawat et al. (2008), Misbah Sadiq et al. (2021), evaluated the bivariate models.

Finally, and used the multivariate models in their studies. The two variable relationship in terms of energy and GDP growth is associated with bivariate models. When production function included energy as a main component with other inputs (i.e., labour and capital), then, these models are known as multivariate models. Explained that energy-led growth can be overestimated if other two main factors (capital stock and labour) are not included in the model. The biasness of omitted variables can be minimized though the multivariate model. Therefore, much additional information is enclosed by multivariate model in the analysis of energy-GDP growth analysis.

Muhammad et al. (2021) in their exploration investigated the willingness to pay for renewable power by employing a one-way ANOVA approach. The meetings were led containing 2500 families in 12 significant metropolitan urban communities of Turkey, which depends on the unexpected valuation technique and comprises of 26 inquiries. The outcomes show that for a 20% portion of an environmentally friendly power, middle income pays higher than upper-middle- and lower-middle-income groups. Also, profoundly ecologically cognizant individuals will in general compensation more for a 20% portion of renewable energy sources. Then again, old age and high-paid workers showed a positive and high eagerness to pay for a 30% portion of an environmentally friendly power. Moreover, elementary school and undergrad instructive recorded profoundly critical outcomes for the ability to pay. The outcomes likewise demonstrate that Turkish residents will pay 9.25 TL for a 20% offer and 4.77 TL each month for a 30% portion of renewable power in absolute energy creation. Anser et al. (2021a, b, c) and Rahman andVelayutham (2020) explored the positive impact of Renewable energy sources on South Asian economic growth. Furthermore, the empirical findings of Dell'Anna (2021) demonstrated that investment in Renewable energy sources such as solar PV, wind, hydropower, and geothermal have an influence on the Italian economy.

Nasreen et al. (2017) analysed the conservation hypothesis and provided suggestions for Turkey from 1970 to 2003, 1990 to 2010, on the method of autoregressive distribution lags model and different tests of causality (Lise and Van Montfort, 2007). The link among the development of the economy and consumption of renewable energy has revealed for the "conservation hypothesis" (Ocal and Aslan, 2013). Sadorsky (2009) examined an association for 18 developing countries from 1994 to 2003. The growth in real income per capita shows a statistically significant and positive influence on renewable consumption per capita. Unidirectional causality is observed as of gross domestic product to consumption of "renewable energy" for the USA 1960 to 2007 (Menyah and Wolde-Rufael, 2010).

The growth of "Sustainable Economic Welfare" (WISE) catalogue for 42 states in "Sub-Saharan Africa" from 1985 to 2013, casing the non-defensive public expenses, weighted consumption, unpaid work benefit, net capital growth, cost from social problems, and depletion of the natural environment. The feedback hypothesis supported the WISE instead of sustainable economic well-being. "Panel Data Co-integration and Granger" causation techniques applied to serve GDP that recommended a neutral hypothesis (Menegaki and Tugcu, 2016a, b). Dual welfare measures are proposed in the study of 15 emerging economies from 1995 to 2013 (Menegaki and Tugcu, 2016a, 2016b). These measures include BISEW made up of health expenditure education and, familiar personal usage with durables, net capital growth, and SISEW. It emerged by subtracting forest depletion, energy, mineral, and damages from carbon dioxide emissions from BISEW.

Previously,examine the role of "renewable energy" through multivariate panel data approach for data analysis. They used data set of EU countries from 2003 to 2014 and applied a fixed-effect model. According to the estimates based on the "panel vector error correction model" that is, the PVECM of 20 OECD countries from 1985 to 2005, it was found that the response hypothesis assisted the short-term and long-term two-way connecting associations among economic development and consumption of renewable energy (Apergis and Payne, 2010). Between 1980 and 2006, six Central American countries published similar findings in 80 countries (Apergis and Payne, 2012). The Granger causality shows a bidirectional relationship between usage of "renewable energy" and economic development for Russia, Brazil, China, India, and South Africa countries for the period 1971 to 2010 (Sebri and Salha, 2014), similarly for China for 1977 – 2011 (Lin and Moubarak, 2014). Feedback effects of Q1 to Q4 from 1972 to 2011 were found in Pakistan based on the panel vector error correction (VEC) model and Granger causation (Shahbaz et al., 2015). Net oil importers in North Africa and the Middle East supported the hypothesis during 1980–2012 (Kahia et al., 2017). Between 1990 and 2012, this inspection was conducted in 23 developed and 49 developing countries; the response connection is reinforced (Amri, 2017). For nine Balkan and black sea countries, it has been proved that the causality link is two way between economic development and usage of renewable energy for the period 1990–2012 (Koçak and Sarkgüne, 2017).From the above literature, it is being explained that no such study has been investigated which explores the impact of solar PV, wind power, geothermal, biomass, and hydropower renewable source of energy on Asian economies. Therefore, this research has been examined.

Methodology

This estimation takes a panel data set of selected Asian economies including China, Bangladesh, Sri Lanka, Indonesia, Pakistan, Nepal, Malaysia, and India for the period 1990–2018. The data set is received from "World Development Indicators" (WDI). Although fixed-effect technique is adopted to evaluate the study model with the following general conceptions:

$$Y_{it} = \vartheta_1 + \vartheta_t + \vartheta_1 X_{it} + \vartheta_2 Z_{it} + \varepsilon_{it} \quad i = 1,2,\dots 8 t = 1990,1991,\dots,2018 \tag{1}$$

where "Y" represents the dependent variable, one-to-one concerning logarithmic values like GDP per capita; "X" signifies the elaborating design for the renewable energy sources, overall and through type; "Z" demonstrates control variables, ε_{it} is the error term; whereas "t" is used for the time horizon and "i" is the country domain. The fixed-effects method was used in this analysis to resolve the biases caused by omitted variables. Furthermore, it employed Pedroni's "heterogeneous panel co-integration test" (1999, 2000). This approach allows for cross-sectional alliance with distinct effects that are distinct from one another.

Unit root test

Numerous researches like Kahia et al. (2017), Li et al. (2021), Uroos et al. (2021), Yikun et al. (2021), and practiced ImPesaran and Shin (IPS) technique recognized by Im et al. (2003). But this study employed a "heterogeneous panel co-integration test" determinate by Pedroni (1990 and 2000).

$$Y_{it} = \varphi_i + \varphi_t + \varphi_1 y_{it} + \varphi_2 x_{it} + \varepsilon_{it} \quad i = 1,2,\dots 8 t = 1990,1991,\dots 2018 \tag{2}$$

$$\varepsilon_{it} = \sum\nolimits_{j=1}^{pi} \theta_{it}\varepsilon_{it} + u_{it} \tag{3}$$

The following Eq. (4) form is obtained by integrating the third and second equations:

$$Y_{it} = \varphi_i + \varphi_t + \varphi_1 y_{it} + \varphi_2 x_{it} + \sum\nolimits_{j=1}^{pi} \theta_{it}\varepsilon_{it} + u_{it} \tag{4}$$

In the expanded "dickey fuller regression," φ_i stands for the number of lags. Panel co-integration investigation was used in this research. Checking for the existence of a unit root estimation of the data sequence is needed when looking into "panel co-integration." In contrast to Chou and Lee (2003), Lee et al. (1997), Saleem et al. (2019a, b), and Sarantis and Steward (1999).

$$GDPC_{it} = \alpha_i + \alpha_t + \alpha_{1i} PRE_{it} + \alpha_{2i} ED_{it} + \varepsilon_{it} \tag{5}$$

Although the parameters α_i and α_t are consent for an economy with the modified tendencies and defined fixed effects, ε_{it} indicates the expected residuals, which demonstrates the disbandment of the alliance in the long run. Meanwhile, the null hypothesis uncovers that there is no co-integration for unbalanced residuals.

Results and discussions

Summary statistics of the variables

The summary statistics are shown in Tables 1, 2, 3, and 4. The tables' overview statistics demonstrate that renewable energy sources account for 14% of gross final energy use, 3% of transportation fuel consumption, 17% of electricity

Table 1 Sustainable economic growth and renewable energy

Variables	Std. Dev	Mean	Maximum	Minimum	Observations
Variables towards sustainable economic growth					
GDPC	13,387.37	22,467.55	743,111.06	3764.41	232
Variables towards renewable energy (overall)					
PRE	4323.16	3971.43	22,455.90	0.22	232
CRE	4327.31	3932.28	21,007.30	0.21	232
EGRS	0.14	0.17	0.58	0.01	232
SRE_FCT	0.01	0.03	0.21	0.00	232
SRE_H	0.10	0.13	0.42	0.00	232

generation from renewable resources, and 15% of ultimate renewable energy use in households.

We estimated all primary factors, such as solid fuel production (excluding charcoal), biodiesel (B-diesels), municipal waste (MW), and other liquid fuels (OLF); wind, geothermal, and hydro drafted the maximum mean estimates, excluding other liquid fuels (OLF), bio gasoline as presented in Tables 1 and 2. Furthermore, as opposed to pollutant emissions and greenhouse gas emissions (GGE) from transportation, cross-sectional level-controlled variables for energy dependency of particular countries (ED), research and development spending in respects of GDP percentage

Table 2 Country-level control variables

Variables	Std. dev	Mean	Maximum	Minimum	Observations
RP	0.56	1.02	2.92	0.37	232
GGE	21.01	71.11	121.11	21.03	232
RD	0.02	0.03	0.06	0.01	232
LF	6,578,006.10	5,301,303.19	24,100,432.05	100,411.45	232
ED	1.13	0.42	0.24	0.09	232
PE_T	14.21	70.01	116.35	32.12	232

Table 3 Co-integration

On level								
Variables	Individual intercept and trend				Individual intercept			
	IPS	PP	ADF	LLC	IPS	PP	ADF	LLC
CRE	0.20	71.06*	41.08	3.05***	0.69	91.08***	30.98	4.60***
PRE	1.01	98.09***	60.10	5.79***	3.09	71.99*	30.91	5.09***
SRE_H	0.05	99.08***	44.29	3.24***	2.29	32.00	22.49	0.06
QSRE_FCT	0.39	42.99	61.00	4.90***	0.49	41.09	42.09	2.09***
EGRS	3.15	48.49	28.05	1.32*	8.30	11.28	4.20	5.59
BGAS	3.09**	95.24***	86.15**	5.10***	3.10	61.00	50.15	3.19**
SBIOFUELS	0.59	53.09*	35.09	2.09***	0.50	65.61*	52.70	4.07***
BGASOLINE	3.59**	22.99	43.09	20.99***	4.9***	37.00	53.00**	17.00***
MW	0.11	44.20*	31.60	4.19***	0.38	41.90	31.59	3.15***
GDPC	0.39	70.00	64.90	5.09***	210**	153.01***	80.09**	5.90***
BDIESELS	0.60	80.18**	40.66	4.20***	1.40*	104.00***	70.09*	6.30***
HYDRO	3.10***	166.09***	104.69***	14.09***	6.09***	209.08***	103.01***	7.69***
WIND	0.10	82.14***	51.10	5.10***	3.00**	131.10***	93.00***	11.00***
GEOTHERMAL	93.08***	43.09	51.00*	604.01***	60.56***	42.09**	54.09*	160.09***
LF	0.70	63.40*	42.99	3.09***	1.19*	103.09***	74.55*	7.08***
PE_T	1.49*	96.10***	73.19*	6.10***	2.69	21.14	32.18	1.41*
GGE	1.29	117.22***	63.23	5.39***	4.27	21.92	22.19	2.34
RD	0.16	80.09**	54.29	3.17***	2.70	25.90	51.14	2.7**
RP	1.59	92.00***	41.99	2.59***	3.79	13.79	14.29	0.29
OLF	0.49	52.49***	24.01	2.90***	0.04	33.59*	20.09	0.59
ED	3.14**	197.49***	82.89**	5.19***	2.13	56.98	20.60	0.30

Table 4 Co-integration

First difference								
Variables	Individual intercept and trend				Individual intercept			
	ADF	IPS	PP	LLC	ADF	IPS	PP	LLC
ΔRD	70.00***	0.30**	167.99***	−4.00***	85.09***	2.90***	180.00***	−4.09***
ΔGDPC	73.09	0.09	77.09*	10.09***	83.16**	2.39**	107.09***	7.80***
ΔPE_T	81.29*	0.09	143.69***	5.50***	161.00***	4.29***	178.00***	7.69***
ΔCRE	91.34**	2.95*	199.72***	12.37***	107.16***	4.52***	208.29***	7.19***
ΔED	109.32***	2.33**	342.02***	5.03***	154.00***	7.14***	354.11***	7.09***
ΔPRE	99.19***	2.80**	215.09***	9.09***	145.10***	6.19***	232.61***	9.09***
ΔGEOTHERMAL	73.15***	31.16***	152.15***	316.16***	92.93***	84.12***	137.515***	472.19***
ΔBGAS	112.19***	4.19***	213.09***	10.09	164.09***	6.09***	237.09***	10.09***
ΔOLF	22.09	0.19	70.49***	3.09**	33.69*	2.09*	76.49***	4.09***
ΔBDIESELS	108.09***	4.09***	208.06***	16.24***	95.92***	3.84***	181.00***	8.19***
ΔBGASOLINE	57.09**	1.09	129.09***	11.09***	70.19***	5.11***	96.09***	14.16***
ΔHYDRO	118.52***	3.94***	279.63***	14.74***	174.44***	8.09***	309.09***	14.69***
ΔMW	35.72	0.02	125.86***	1.09	54.39*	2.01*	114.86***	3.14**
ΔWIND	105.00***	2.12**	245.00***	10.33***	117.17***	4.90***	241.44**	6.42***
ΔSBIOFUELS	67.11	0.29	227.11***	3.21***	96.15***	3.02***	210.63***	5.02***
ΔGGE	115.84***	3.41***	256.20***	11.45***	141.46***	6.34***	246.14***	10.53***
ΔSRE_FCT	65.69	0.25	123.25***	6.59***	89.21***	3.00***	153.11***	5.32***
ΔRP	105.39***	2.09**	251.18***	10.09***	116.09***	−4.11***	254.00***	−6.54***
ΔEGRS	86.49**	1.14	140.14***	10.12***	54.20	0.04	105.62***	1.49*
ΔLF	76.22*	1.05	233.63***	2.87**	81.48*	2.29*	176.39***	2.29**
ΔSRE_H	53.00	0.34	203.67***	4.44***	98.89***	3.87***	243.77***	6.29***

(RD) and resource productivity (RP), and pollution discharge from transport have low mean values (PE_T).

Co-integration and causality examination

The association between the LLC with the remaining variables is shown in Table 3. The LLC analysis uncovers that the variables LF, GDPC, RD, PRE, PE_T, CRE, HYDRO, WIND, and SER_FCT all are stationary at level. The analysis of the panel unit root is revealed in Table 4. Pedroni (2004) inspection has the following ways: without intercept or trend, with particular intercept and trend, and with individual intercept. When the majority of the factors are significant, co-integration occurs in the model, and the (FMOLS) panel pattern can be used.

Analysis of fixed effects

The case of the three anticipated models is defined in Table 5. Greenhouse gas emissions (GGE) and production of renewable energy (PRE) are significantly associated via sustainable growth in model 1. We dropped PRE in model 2 and incorporated variable consumption of renewable energy source (CRE), which is directly related to sustainable growth (see Table 5). The effect of hydropower, wind energy, and geothermal energy on sustainable economic advancement is shown in Table 6. The findings of this study show that in the illustration of model 1, the factor HYDRO has an insignificant impact on sustainable economic growth. This means that conserving hydroelectricity by bringing up energy conservation policies would have no effect on economic growth in these nations. GEOTHERMAL is incorporated in model 2 and displays a positive as well as significant impact on growth. While in our analysis, third model demonstrates that the variable WIND has a significant impact on growth. On the other hand, Bilgili and Kuskaya (2019), Ewing et al. (2007), Bulutand Inglesi-Lotz (2019), and Menegaki and Tugcu (2016a, b) all came to similar conclusions. Although solar PV energy has insignificant impact on economic growth (Table 7).

The Kao test estimates are described in Table 8. The test uses pooled regression to assess uniform co-integration associations when taking each fixed effect into account. To support that the co-integration vector is stable, we practiced the ADF panel co-integration attempt,

Table 5 Estimations of fixed-effects

Variables	Model (1)	Model (2)	Model (3)
SRE_FCT	1.09***		
	(0.00)		
CRE		0.19***	
		(0.00)	
PRE			0.10***
			(0.01)
PE_T	0.12	0.04	0.02
	(0.51)	(0.87)	(0.90)
ED	0.23	0.32	0.02
	(0.98)	(0.89)	(1.21)
GGE	0.11*	0.27*	0.19***
	(0.09)	(0.08)	(0.00)
PE_T	0.12	0.01	0.02
	(0.41)	(0.26)	(0.14)
RP	0.12	0.11	0.01
	(0.23)	(0.90)	(0.98)
LF	0.22	0.32	0.08
	(0.24)	(0.54)	(0.45)
RD	5.43*	6.19**	6.00**
	(0.06)	(0.04)	(0.03)
Constants	12.15***	12.04***	8.08***
	(0.00)	(0.00)	(0.00)
F statistic	7.19***	8.11***	7.11***
Observations	232	232	232
R-sq within	0.20	0.16	0.22

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$ and $p < 0.1$

which uncovered co-integration between unique variables. The outcomes of the Fisher test are described in Table 9.

Table 7 illustrates the effect of "hydropower, geothermal energy, wind energy, and solar energy" on sustainable economic growth, which demonstrates the positive but insignificant impact of hydropower renewable energy source on the economic growth of Asian economies. Although this result contradicts the empirical finding of Ummalla et al. (2019), which explores a positive and significant impact of hydropower sources of energy, we find a positive and significant impact of wind power on Asian economic growth.[1] Although Mikuli et al. (2018) discovered that the installation of wind energy plants in Croatia has favourable indirect as well as induced benefits, our study results confirm the positive insignificant impact of solar PV on the economic growth of these nations, which are consistent with findings of Bulut and Menegaki's (2020) in which they examined that solar PV has an insignificant impact on the economies of the USA, China, Spain, Australia, India, the UK, Japan, Italy, and Germany. Besides that, biomass renewable energy sources have a significant positive impact on our exploration (please see Table 7). Since biomass-based renewable energy potential promotes sustainable development, Ozturk et al. (2017) empirical exploration suggests that Malaysia and Turkey require additional research to design and frame policies at various levels to enhance biomass consumption, and to voice their experiences. In addition, geothermal source of energy has also a significant impact on the economic growth of Asian economies. In fact, Yan and Qin (2017) revealed the socio-economic advantages of geothermal power deployment for the Chinese economy.

The above Tables 8 and 9 shows long-run correlation association in both Kao test and Fisher test estimators. We assess this relationship using the panel pooled technique. Table 10 shows that a 1% rise in power sources results in a 0.07% growth in total national production per capita (if the "FMOLS" model is experienced for evaluation) conversely 0.06 percent growth in total national output per capita (if the "DOLS" model is adopted for evaluation). The lag length was determined by using the Akaike information benchmark.

We discovered a causal association between vitality dependency and per capita GNP by using the "PVECM Granger causality" in the imperative sustainable energy power generation, and the findings are represented in Table 11. As exposed in Eqs. (6)–(8), this table depicts the estimated post-effects axioms for short- and long-term transport elements. The Schwarz information standard uncovered a two-lag model, like Eq. (6) from Table 11 displays, with the formation of sustainable renewable energy sources having an insignificant long-term effect on total national output per capita. Equation (8) indicates that GDP per capita has a short-term impact on the remarkable formation of sustainable power authorities, and the protection hypothesis is comparable in this regard. Besides that, Eq. (7) demonstrates that in the long run, the development of sustainable power authorities has a significant impact on vitality dependence.

Discussion and conclusion

This research unearths the renewable power sources' impact on the economic growth of Asian economies in order to fill the gap in the empirical literature. The finding of this study reveals the positive and significant effect of wind power, geothermal, and biomass on the Asian economies. Meanwhile, the influence of hydropower and solar power is positive but insignificant on these

[1] Gonçalves et al. (2020) explored the sectoral impact of wind energy sources on the construction, industrial, and agricultural sectors of the Brazilian economy.

Table 6 Estimations of fixed-effects for economic growth sustainability and biomass energy

Variables	Model (1)	Model (2)	Model (3)	Model (4)
BGASOLINE	0.13*** (0.00)			
MW		0.10*** (0.00)		
BGAS			0.04*** (0.00)	
SBIOFUELS				0.20*** (0.00)
GGE	0.01** (0.04)	0.29*** (0.00)	0.90** (0.04)	0.41*** (0.00)
ED	0.15 (0.43)	0.32** (0.05)	0.13 (0.63)	0.21 (1.62)
RP	0.12 (5.00)	0.12 (0.14)	0.01 (0.32)	0.10 (0.29)
PE_T	0.14 (1.39)	0.12 (0.31)	0.12 (0.59)	0.12 (0.14)
LF	0.12 (0.31)	0.02 (0.12)	0.15 (0.27)	0.12 (0.11)
RD	6.11** (0.03)	4.98* (0.09)	6.58** (0.04)	5.11** (0.03)
Constant	8.09*** (0.00)	7.62*** (0.00)	7.32*** (0.00)	5.76*** (0.00)
R-sq within	0.22	0.23	0.20	0.21
F statistic	10.13***	11.05***	7.95***	8.80***
Observations	232	232	232	232

nations (For details see Table 7). The findings suggest that power generation from renewable sources has a significant impact on Asia's economic growth. In contrast, ecologists and power specialists have conducted similar research to gather information. Ishaque's (2017) 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 solar PV and wind power renewable sources in the context of Pakistan, and our study comprises of hydropower, wind power, solar PV, biomass, and geothermal as a source of renewable energy in the context of Asian economies. Moreover, the results of our study are to some extent comparable with some of the foreign studies on this area of research for instance, Bilgili et al. (2019a, b), Li et al. (2021). The findings of our study are similar to several studies, such as Ewing et al. (2007), Bilgili and Ozturk (2015), Bildirici and Gokmenoglu (2017), Bilgili et al. (2019a, b), and Bulut and Iglesi-Lotz (2019). Shahbaz et al. (2015) looked at the effect of biomass energy use on BRICS economic growth.

The findings of current research have significant implications towards Asian countries' energy policy related to both private and public sector enterprises as it helps in identifying the industrial sectors which have greater contribution towards the economy and their energy requirements in long term, whereas the data set of this study is very helpful for power generation companies as it enables them to plan their potential projects in such a way that they not only fulfil the energy requirements of specific sector but are financially sustainable in the future. Such information is also helpful in capital budgeting decisions such as payback

Table 7 Analysis of fixed-effects concerning solar energy, hydropower, wind, and geothermal energy on economic growth sustainability

Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
Hydropower	0.03 (0.57)				
Geothermal energy		0.02** (0.05)			
Wind power			0.70*** (0.00)		
Solar PV				0.03 (0.45)	
Biomass					0.49*** (0.00)
ED	0.21* (0.09)	0.23 * (0.09)	0.31* (0.08)	0.11* (0.09)	0.10* (0.08)
PE_T	0.11 (1.54)	0.13 (1.37)	0.36 (0.55)	0.15 (0.76)	0.04 (0.79)
GGE	0.20* (0.09)	0.40** (0.05)	0.20*** (0.00)	0.03*** (0.01)	0.04*** (0.00)
RD	4.32*** (0.00)	6.75 ** (0.01)	7.19*** (0.00)	5.03*** (0.00)	3.10*** (0.00)
RP	0.02* (0.09)	0.13** (0.04)	0.20* (0.07)	0.30** (0.03)	0.01* (0.07)
Constants	7.42** (0.02)	6.48*** (0.01)	7.41*** (0.00)	5.81*** (0.00)	4.49*** (0.00)
LF	0.02 (0.03)	0.01 (0.14)	0.03 (0.54)	0.02 (0.23)	0.01 (0.39)
F-statistic	6.00***	6.09***	24.09***	15.09***	11.98**
Observations	232	232	232	232	232
R-sq within	0.11	0.10	0.24	0.22	0.25

Table 8 Kao test estimates (Engle Granger based)

ADF (*T*-statistic)	HAC variance	Residual variance
4.09***	0.003	0.002

Source: authors' own computations. Akaike Information Criterion was picked for lag length and ***$p < 0.001$.

period and other advanced techniques as it establishes the long-term relationship, which is crucial for accurate financial prediction.

Table 9 Fisher test estimates (combined Johansen)

Hypothesized no. of CE(s)	Fisher stat. (from max-Eigen test)	Fisher stat. (from trace test)
None	480.99***	509.9***
At most 1	111.00***	124.90***
At most 2	92.90***	96.00***

***$p < 0.001$.

Table 10 The output of the panel fully dynamic OLS (DOLS) and modified OLS (FMOLS)

Variables	DOLS	FMOLS
ED	0.21 (1.38)	0.07 (1.90)
PRE	0.03*** (0.00)	0.06*** (0.00)
Adjusted *R*-squared	0.93	0.94
S.E. of regression	0.03	0.03
R-squared	0.95	0.97
Mean dependent var	8.02	9.23
Durbin-Watson stat	0.23	0.30
S.D. dependent var	0.60	0.57
Sum squared resid	1.70	1.42
Long-run variance	0.01	0.01

Source: authors' own computations. Panel method: pooled, ***$p < 0.001$.

Table 11 Granger causality and PVECM

	Weak or short-run Granger causality	Long-run Granger causality		
Variables	DPRE	DGDPC	DED	ECT
ΔED(6)	4.21	1.85	_	0.02***
ΔPRE(7)	_	1.30	3.20	0.03**
ΔGDPC(8)	9.14**	_	3.12	0.01

Source: authors' own computations. ***$p < 0.001$, **$p < 0.01$, and $p < 0.1$

Finally, for both renewable and conventional segments of the energy sector, using the speed of adjustment estimates, the companies could gauge the behavioural aspect of the consumers in short-run and such fluctuations in demand can also be incorporated in the capital budgeting aspects of the power supply companies for strategic decision making and future policy determinations. Furthermore, the production and consumption of wind power, geothermal, and biomass are amongst the major drivers of economic progress due to its low cost and minimum carbon omission in the case of Asian countries; the policymakers should talk out the incentive-based policies to promote this source of electricity (Anser et al., 2021a, b, c; Khan et al., 2021; Maji et al., 2019 and Jun et al., 2021). This study emphasizes that renewable sources of energy should be incorporated in the sustainable or green growth agenda. Moreover, in order to explore further, this research can be explored by incorporating various renewable sources of energy and investigate their impact on consumers as well as producers' well-being and contrasts them and suggests policy implications for individual nations, as our exploration is limited to explore the impact of distinct renewable sources of energy on the environmental growth of Asian economies.

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Data availability The data is available on request from the corresponding author.

Declarations

Ethical approval and consent to participate This study did not use any kind of human participants or human data, which require any kind of approval.

Consent for publication Our study did not use any kind of Individual data such as video, images etc.

Competing interests The authors declare no competing interests.

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