

Article

Exploring the Relationship between Renewable Energy Sources and Economic Growth. The Case of SAARC Countries

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Abstract: The purpose of this study is to examine the relationship between renewable energy sources and economic growth of the South Asian Association for regional cooperation (SAARC) countries. This study uses three main renewable energy sources, namely geothermal, hydro, and wind. This study collects data set from SAARC countries from 1995 to 2018 and applies a fixed effect test and panel vector error correction model (PVECM) for data analysis. The overall results show that all three renewable energy sources have a positive significant impact on economic development among SAARC countries' economies. Moreover, hydropower renewable energy has more effects and influences on economic growth as compared to the other two individual sources of renewable energy.

Keywords: renewable energy sources; sustainable economic growth; SAARC countries



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1. Introduction

Renewable energy sources are an important component of economic development. In contemporary times, the population is increasing worldwide enormously, and consequently, the demand for the generation of energy from exhaustible conventional resources has increased. Therefore, environmental concerns and energy price rises jeopardize the sustainability of the growing economy. Contrarily, renewable energy is formed after refilled natural resources to enhance energy security and catering to the issues of climate change and global warming. Renewable energy signifies a necessary element for accomplishing sustainable economic development [1]. For instance, the Administration of Energy Information (AIE) from the United States of America (USA) and Outlook of International Energy (2016) stated that a 48% increase in the utilization of global energy would be required by the year 2040 and the requirement for a decrease in carbon components is noticeable.

Conventional energy is generated from limited resources and the governing bodies deliberate an appropriate use of this energy. If the requirements of the current population are satisfied without destabilization and the capability fulfills the needs of forthcoming generations, this is considered sustainable growth. A sustainable economy depends on the mobility and externalities of resource use. Moldan and Janoušková [2] and Beça and Santos [3] suggested three dimensions, i.e., social, economic, and environment, of sustainable growth. It is crucial to consider natural deficiency, including social welfare for sustainable development. The sustainability of economic development exposes the way to resolve the weather modifications and disasters, as well as responses to ecological, economic, and social crises that influence the population [4].

Energy is the main ingredient in the process of production. It is the backbone of the industrial sector. The targets of economic growth cannot be achieved without the use of energy sources, a rise in economic growth increases the level of energy use, and both move in parallel together [4]. Since 1973, during the phase of oil crises, the theory of unit elasticity has become more important. According to unit elasticity, a one-unit change of the economic growth leads to a one unit change in the use of energy sources in the Organization for Economic Co-operation and Development's (OECD) countries during (1973–1974) oil crises [4].

However, since the late 1970s, recorded elasticity has been less than 1% or if there was a 1% increase in economic growth, it has led to a decrease of energy use of less than 1% for the OECD economies. Since 1973, the economic growth–energy use nexus observations and their trends showed that energy is essential for GDP growth and trends indicated the important role of energy in GDP growth. However, a tremendous change can be seen in this energy growth after the 1973 relationship, especially in developed countries. Moreover, the elasticity of energy sources concerning GDP is equal to one or greater than one found in developing countries, but in developed countries, energy use elasticity is less than one (e.g., 0.8 or in between 0.9). The lack of technological development as well as the non-efficient use of energy sources in developing countries has led to more use of energy sources. On the other side, efficient utilization of energy sources in other sectors with technological development decreases the intensity of energy consumption, as supported by Babusiaux and Pierru [5] in their analysis.

Hydroelectricity, wind, geothermal, solar, and biomass are considered renewable sources of energy, as nature can replenish such sources with time. According to Fang [6], the two major expectations from these sources of energy by major stakeholders, such as policymakers and the general public, mainly relate to fulfilling the energy requirements of the economy, which can result in sustainable economic growth. The second relates to the conservation and protection of the environment for present and future generations, which has been degrading at an alarming pace due to the use of fossil fuels. Solar energy, in the form of heat and radiations, consists of radiant light and heat from sun, which is being harvested by a diverse range of ever-changing and constantly developing technologies, such as solar thermal energy, solar architecture, solar heating, molten salt power plants, and artificial photosynthesis. The large magnitude of solar power available makes highly appealing source of electricity, in that approximately 30% of solar radiation is reflected back into space while the rest is absorbed by oceans, clouds, and land masses. In general, cells convert solar radiation directly into electricity, using various kinds of semiconductor materials.

The SAARC economies are trying to increase the level of competition and economic growth; thus, renewable energy is playing an important role and can produce sustainable economic growth in developing countries. Moreover, SAARC countries have been facing a significant energy shortfall for the last decades, especially after 9/11 and the subsequent war against terrorism in Afghanistan. In this context, several countries from this region are trying to use alternative energy sources or reproduce energy through circular economy in order to stabilize their industry and economy. The economy's growth (measured by GDP growth) is highly connected with renewable energy usage and taken as a measure for the "oxygen" for the whole world's countries. Renewable energy is considered by [7] to be a prerequisite for the achievement of economic growth. While in various developing countries, a significant proportion of their inhabitants (especially SAARC countries) are living below the poverty line, many SAARC countries are trying to achieve economic growth through industrialization, globalization, and trade liberalization, in order to lift millions of inhabitants out of poverty.

The present study has been divided into four distinct points to better understand the relationship between independent and dependent variables. First, the novelty of this research explains the effects of renewable sources of energy, by type or total, on the sustainable growth of economies of South Asian countries from 1995 to 2018. Successively, the underlying connection between renewable energy, GDP (per capita), and energy de-

pendence are investigated by an empirical approach. This study analyses five different sources of renewable energy and their effect on South Asian economies and it is different from the preliminary investigations to some extent. In particular, the innovation of this research supervenes from investigating the consequences of renewable sources. Second, the paper reveals the causal relationship between the production of renewable energy, energy dependence, and economic growth, regarding capital formation, consumption of renewable energy, and the labor force of South Asian economies.

Third, our research contributes to the existing body of knowledge on the given subject matter by analyzing the association of the consumption of renewable energy in form of hydroelectricity and its impact on economic growth. The importance of this topic also comes to light when we consider the fact that the eight countries were chosen for purpose of this study with some countries ranking as top pollutants, and considering the minimal impact of hydroelectricity on the environment.

The present research is contributing to a limited set of studies consisting only of two prior studies: first by Omay and Kan [8] and second by Apergis and Apergis [9] who had earlier employed the technique of “nonlinear panel smooth transition vector error correction model” to assess the impact of electricity consumption on the growth of the economy. Omay and Kan [8] analyzed the consumption of total electricity while Apergis and Apergis [9] used the total consumption of renewable electricity for their analysis. For the purpose of this study, we mainly focus on the consumption of hydroelectricity as the previous studies seems to lack this aspect, but at the same time we use the same technique i.e., “nonlinear panel smooth transition vector error correction model” for our analysis as justified by our literature review. Fourth, it relates to fact that we have used panel data rather than time-series data to establish the causal relationships between the above-mentioned factors as this approach reduces the issues relating to multicollinearity and provides much better estimates as compared to time series data.

2. Literature Review

The literature on energy use and economic growth nexus has been well discussed by researchers and economists from the last few decades. The proposal of energy led growth nexus is first time discussed by Kraft and Kraft [10] in their study. Now, this topic is still under investigation by many researchers. Overtime, different economists have introduced various theories of economic growth, but energy development as a key ingredient of economic growth is neglected by these growth theories. Technological advancement is an important component of economic growth in the Solow model of growth. Likewise, innovation and capital formation are considered as the most important determinants of economic growth in Schumpeter’s model.

Renewable energy consumption has a direct influence on the growth of the economy according to the growth hypothesis in 57% of the top 38 states of renewable energy consumption [11]. Bulut and Inglesi-Lotz [12] reveals the statistically significant and positive influence of renewable energy consumption on economic development in 34 OECD countries. The feedback hypothesis has shown economic development and usage of biomass energy for Q1 of 1991 to Q4 of 2015 for the countries of the BRICS region [13]. Among seven Latin American countries, for 1970 to 2012, long-run bidirectional causality has been observed among economic development and hydroelectricity usage in Venezuela and Argentina, while long-run unidirectional causality is supported by the use of hydroelectricity to growing economy in Chile, Brazil, Ecuador, Colombia, and Peru [14]. Multivarious causality results have been concluded by Menegaki and Tugcu [4] based on seemingly unrelated and Granger causality regression. For G7 countries, basic ISEW comprising of only economic variables and solid “ISEW” covering the totality of environmental and economic variables have been computed for 1995 to 2013 [4].

Energy is a main ingredient in the process of production and the backbone of the industrial sector. In this sense, the targets of economic growth cannot be achieved without the use of energy sources, and concurrently economic growth increases the level of energy

use. Since 1973, during the period of oil crises, the theory of unit elasticity has taken importance. According to this theory, a unit change of economic growth leads to one unit change in use of energy sources, as was apparent in OECD countries during the 1973–74 oil crises.

On the other hand, since the late 1970s, elasticity is recorded at less than 1 percent, i.e., a 1% increase in economic growth is associated with a less than 1% increase in energy use in OECD economies [15]. Since 1973, observations and trends of the economic growth–energy use nexus showed that energy is essential for GDP growth. However, a significant difference can be seen between developing and developed countries after 1973: while energy use elasticity with respect to GDP is less than 1 in the latter countries, the elasticity coefficient in developing countries is greater than 1.

The first theoretical discussion of the energy-led growth nexus is the study of Kraft [10], which was further developed by Schurr and Darmstadter [16], who described that the living standard of citizens can be improved by energy use and that economic growth increases with the increase in the level of energy use. The analysis of Barney and Franzi [17] explored energy as a key determinant of economic growth, playing a vital role in industrial production.

The growth of the economy highly depends on the energy sources. Khuong and Shabbir [18] examined a possible correlation between the use of energy sources and the level of economic growth. The production process of the goods requires energy as a compulsory input and without energy, various economic activities cannot grow. Moreover, modern economic growth needs energy for industrial growth, productivity, and trade as well. Shabbir (2016) evaluated the cause and effect of economic growth and use of energy sources; economic growth significantly amplifies the level of energy use and in return energy significantly upsurges the level of GDP growth. The energy–growth nexus has been discussed in various empirical studies, but results are still inconclusive. Thus, since the work of Kraft and Kraft [10], various researchers examined the energy-growth correlation for different countries. Numerous studies used different econometric techniques for different periods of time and for country-specific or different cross-country studies, to investigate the link between energy and growth. Magazzino [19] and various other researchers like Ozturk and Bilgili [20] examined the link between growth and energy and presented the previous literature and surveys in the field.

The underlying relationship between the consumption of renewable energy and economic growth has been the subject of many studies over the last few decades. Payne [21] held that results, in general, are mixed. Numerous studies provide extensive literature on the development of the economic and depletion of renewable sources of energy [6,22,23]. There are several types of studies on the correlation between biomass energy and economic development [18,24,25], hydroelectricity consumption, and economic development [9,25]. For the case of the US, Yildirim and Saraç [23] have considered various types of renewable energy. Four testable hypotheses investigate the underlying affiliation concerning economic development and renewable energy consumption that includes feedback, conservation, growth, and neutrality [9].

Meanwhile, Ohler and Fetters [26], rather than restricting themselves to the consumption of electricity, focused on the consumption of renewable electricity and analyzed its impact on the level of economic activities. One of the pioneering studies in this regard was conducted by Abakah [27], who conducted his study by analyzing the consumption of hydroelectricity and its impact on the economic growth of Ghana, using data from 1971 to 1990. The results of the study suggested the existence of an inverse relationship between the electricity produced from coal and economic growth and a positive relationship between economic growth and hydroelectricity. This flowed by examination of the causal relationship between economic growth and the consumption of renewable electricity by Apergis and Apergis [9]. Their study was based on data for economic growth and electricity consumption for thirteen Eurasian countries, from 1992 to 2007. The variables employed in the multivariate panel data model were labor force, the formation of gross fixed capital, GDP, and the consumption of electricity made from renewable energy. The results of the

panel cointegration test revealed a long-run relationship between the variables. The results also indicated the existence of a bidirectional causality amongst the economic growth and the consumption of renewable electricity on short and long-run.

Apergis and Apergis [9] conducted a similar study on the panel data of twenty OECD countries by using data for the economic growth and energy consumption from 1985 to 2005. Unlike the previous study, they considered labor and capital as control variables as they applied a multivariate framework. The unit root test suggested by Im and Pesaran [28] indicated that all variables were integrated of the first order. The heterogeneous panel cointegration test suggested by Pedroni [29] revealed a long-term relationship between the variables. Meanwhile, the results of Granger's causality test indicated the presence of a bidirectional causality amongst the basic variables of economic growth and the consumption of renewable electricity.

Furthermore, Rosenberg [30] argued that the living standard of citizens can be improved by energy use, and that economic growth increases with an increase in the level of energy use. Barney and Franz [17] considered energy as a key determinant of economic growth and playing a vital role in industrial production. Furthermore, Grossman and Helpman [31] introduced research and development as an important component of economic growth. Kraft and Kraft (1978) are the ones that provided new insights into the economic growth models and discussed that energy is essential for the production process.

Armeanu, Vintilă [32] examine the role of "renewable energy" and its causal relationship with sustainable progress. Using the data for EU countries from 2003 to 2014, applying a fixed-effect model he reveals a positive correlation between renewable energy and GDP development. Likewise, Nasreen and Anwar [33] analyzed the relationship between energy consumption, financial development, and environmental quality. They used data sets for South Asian countries from 1980 to 2012 and applied cointegration techniques to reveal that the financial sector development enhances environmental quality and economic growth. Furthermore, they also show that energy consumption deteriorates the environmental quality and growth level.

3. Material and Methods

3.1. Data and Sample

This study investigates the impact of three renewable energy sources such as hydro, geothermal, and wind on economic growth of south Asian economies between 1995 and 2018. We didn't find the data set of other energy sources (solar, biomass etc.), which start from that time period, that's why we have chosen these three energy sources in our study. We used data sets collected from "World Development Indicators" (WDI), World Bank annual reports, as well as south Asian economic surveys published by Asian development bank (ADB). We used gross domestic product (GDP) as a measure for economic growth as several other studies used it, e.g., [34–40]. This study further measures renewable energy (general and by category) and controls the measures at the national level. The goal is to reveal the impact of sustainable energy using panel data. This implies a fixed-effect regression model with the following general specifications:

$$P_{it} = \varphi_i + \varphi_t + \varphi_1 Q_{it} + \varphi_2 R_{it} + \varepsilon_{it} \quad (1)$$

$$i = 1, 2, \dots, 8, \quad t = 1995, \dots, 2018$$

where P , the dependent variable, is measured by the logarithmic values of GDP, Q indicates the construct for the renewable energy sources, by type and overall, R denotes the control variables at the country-level, ε_{it} is the error term, i is the country, and t is the time dimension. In our study, we used a fixed effects model. The panel cointegration test proposed by Pedroni [29] was used to reveal the cross-sectional interdependence with separate effects. Additionally, we will use the heterogeneous board co-combination test created by Pedroni [29] that grants for cross-area association with various individual impacts.

3.2. Model

This study employed a heterogeneous panel cointegration model established by Pedroni [29], which permits interdependence between the cross-sectional unit on account of different individual effects.

$$P_{it} = \varphi_i + \varphi_t + \varphi_1 p_{it} + \varphi_2 Q_{it} + \varepsilon_{it} \quad (2)$$

$$i = 1, 2, \dots, 8, \quad t = 1995, \dots, 2018$$

$$\varepsilon_{it} = \sum_{j=1}^{Si} \theta_{it} \varepsilon_{it} + u_{it} \quad (3)$$

By combining the third equation into the second equation, we can write the following equation:

$$P_{it} = \varphi_i + \varphi_t + \varphi_1 p_{it} + \varphi_2 Q_{it} + \sum_{j=1}^{si} \theta_{it} \varepsilon_{it} + u_{it} \quad (4)$$

where si denotes the sum of lags in the augmented Dickey Fuller test. This study employed a panel cointegration analysis. For this purpose, we have used the LM Pearson and Shin IPS tests (1997). Different researchers such as Khuong and Shabbir [18] and Muhammad and Shabbir [25] used this method in their research to investigate cointegration in panel data.

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

where the parameters α_i and α_t license for a country with the fixed effects and defined tendencies, μ_{it} represents the predictable residuals, which indicates the dispersion of the association in the long run. The null hypothesis reveals that there is no cointegration for non-stationary residuals. Meanwhile, P indicates a reliant variable, separately total national output "per capita" (logarithmic qualities), Q implies the logical factors to a sustainable power source, generally and by type, R speaks to the national control level factors and block ε_{it} is the blunder term, and for states, and t explains the time measurement. Additionally, this study utilizes the heterogeneous board co-combination test created by Pedroni [29] that grants for cross-area association with various individual impacts:

$$GDPC_{it} = \alpha_i + \alpha_t + \alpha_{1i} PRE_{it} + \alpha_{2i} ED_{it} + \varepsilon_{it} \quad (6)$$

$$i = 1, 2, \dots, 8, \quad t = 1995, \dots, 2018$$

where the parameters α_i and α_t allow for nation particular settled impacts and deterministic patterns, ε_{it} represents the estimated residuals which delineate the dispersion from the long-term association. The invalid theory uncovers the absence of co-reconciliation and individual residuals, which are non-stationary. However, Y indicates the dependent variable, separately total national output "per capita" (logarithmic qualities), whereas X implies the logical factors towards the sustainable power source and Z stands for the national level control factors and block parameters areas α_1 and α_2 . It utilizes the heterogeneous board co-combination test created by Pedroni [29] that grants for cross-area association with various individual impacts.

$$GDPC_{it} = \alpha_i + \alpha_t + \alpha_{1i} PRE_{it} + \alpha_{2i} ED_{it} + \varepsilon_{it} \quad (7)$$

$$i = 1, 2 \dots 8, \quad t = 1995 \dots 2018$$

The above Equation (7) defines the parameters as α_{1i} and α_{2i} allow for national settled impacts and deterministic patterns, and μ means the evaluated residuals. The invalid theory uncovers the absence of co-reconciliation, individual residuals, which are non-stationary.

$$GDPC_{it} = \alpha_i + \sum \omega_{ij} \varepsilon_{it-j} + \alpha_t + \alpha_{1i} PRE_{it} + \alpha_{2i} ED_{it} + \varepsilon_{it} \quad (8)$$

Therefore, in subsequent steps, researchers used “modified ordinary least squares” (FMOLS) and dynamic ordinary least square estimators (DOLS) as (Nguyen, Basuray [41], Jodeh, Hamed [42]). The panel vector error correction model was developed, and the Granger causality test was also employed. In this study, Engel-Granger’s two-step process is used to estimate the projected residuals. This study addresses the following hypothesis.

Hypothesis 1 (H1). *There is an association between renewable energy sources and GDP growth for SAARC countries.*

4. Results and Discussion

4.1. Descriptive Statistics

Tables 1 and 2 show the descriptive statistics. The summary statistics of the tables show that the share of renewable sources of energy in gross final usage of energy is 13%, the share of the fuel consumption in transportation is 2%, the share of electricity generation by renewable resources in terms of electricity generation is 16%, while the share of final renewable energy usage of the households 15%.

Table 1. Energy and Sustainable Economic Growth.

Variables	Observations	Mean	Std. Dev	Minimum	Maximum
Variables towards sustainable economic growth					
GDP	192	25,023.56	17,21.40	4394.48	964,232.06
	Variables	Towards	Renewable	Energy	(overall)
PRE	192	4651.01	5713.20	0.30	29,027.90
CRE	192	4432.30	5947.70	0.29	28,439.30
SRE_GFEC	192	0.19	0.19	0.09	0.56
SRE_FCT	192	0.05	0.06	0.00	0.21
EGRS	192	0.20	0.18	0.06	0.60
FEC	192	0.19	0.18	0.00	0.56

Table 2. Country-level control variables.

Variables	Observations	Mean	Std. Dev	Minimum	Maximum
ED	192	0.52	0.27	0.44	1.33
GGE	192	81.20	25.39	31.34	135.21
PET	192	80.26	17.35	34.12	123.35
RP	192	1.07	0.59	0.39	2.97
RD	192	0.06	0.07	0.04	0.07
LF	192	6,102,345.19	8,346,289.10	102,433.45	31,342,476.05

We analyzed all primary variables, such as the production of solid fuels excluding charcoal, municipal waste (MW), biodiesel (B-diesels), other liquid fuels (OLB); hydro, geothermal, and wind registered the highest mean values, except bio gasoline, other liquid fuels (OLB) as seen in Table 1. Moreover, cross-sectional level control variables for the energy dependence of specific country (ED), resource productivity (RP), and research and development expenses in terms of GDP percentage (RD) are showing low mean values as compared to greenhouse gas emission (GGE) or pollutant emission from transport (PET).

4.2. Co-Integration

Table 3 shows the relationship between the LLC with other variables. The LLC test reveals that the variables GDP, PRE, CRE, SRE_FCT, HYDRO, WIND, PET, RD, and LF

are at stationary level. Table 4 discloses the output of the panel unit root tests. As shown, all the variables are at a fixed level. Pedroni [29] test has three approaches: with individual intercepts, with individual intercept and trend and without intercept or trend. When most variables are significant, cointegration exists in the model among the variables and the (FMOLS) panel model can be employed.

Table 3. Co-integration (on level).

Variables	Individual Intercept				Individual Intercept and Trend			
	LLC	IPS	ADF	PP	LLC	IPS	ADF	PP
GDP	5.19 ***	113 **	82.84 **	155.04 ***	5.62 ***	0.42	64.05	69.46
PRE	5.20 ***	211	32.52	73.96 *	5.91 ***	1.03	62.08	98.21 ***
CRE	4.47 ***	0.80	33.79	91.04 ***	3.15 ***	0.15	42.43	72.51 *
SRE_GFEC	3.15	5.22	10.31	11.22	3.19 ***	0.27	53.27	73.34 *
SRE_FCT	2.14 ***	0.72	44.54	43.02	4.20 ***	0.50	61.14	44.53
EGRS	5.45	8.41	4.20	12.18	1.25 *	4.16	28.16	49.38
FEC	0.06	2.26	23.52	32	3.20 ***	0.06	43.33	99.09 ***
MW	3.45 ***	0.68	32.73	42.48	4.27 ***	0.16	32.68	45.15 *
OLB	0.62	0.15	21.19	34.61 *	2.96 ***	0.57	25.11	53.51 ***
HYDRO	7.79 ***	6.73 ***	102.61 ***	208.18 ***	14.20 ***	3.10 ***	106.73 ***	167.45 ***
GEO_THERMAL	160.34 ***	61.66 ***	53.11 *	41.71 **	605.31 ***	93.43 ***	52.83 *	44.63
WIND	11.29 ***	2.24 **	94.03 ***	142.18 ***	5.10 ***	0.07	54.10	84.14 ***
ED	0.35	2.20	19.66	57.88	6.21 ***	2.15 **	81.79 **	196.50 ***
GGE	2.40	5.17	22.19	22.62	4.41 ***	2.31	61.33	118.12 ***
PET	1.81 *	3.72	31.08	22.03	7.09 ***	3.51 *	74.01 *	97.09 ***
RP	0.63	2.83	15.12	14.65	3.48 ***	1.65	43.34	92.25 ***
RD	3.6 **	2.56	52.4	26.35	4.18 ***	0.25	55.30	81.55 **
LF	8 ***	1.38	75.55 *	105.09 ***	2.18 ***	0.75	44.20	65.36

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

Table 4. Co-integration (First Difference).

Variables	Individual Intercept				Individual Intercept and Trend			
	LLC	IPS	ADF	PP	LLC	IPS	ADF	PP
Δ GDP	8.76 ***	1.43 **	84.12 **	108.32 ***	11.26 ***	1.97	74.37	79.27 *
Δ PRE	10.28 ***	5.26 ***	148.06 ***	233.75 ***	9.93 ***	3.76 **	96.27 ***	216.12 ***
Δ CRE	8.27 ***	5.62 ***	109.26 ***	209.37 ***	11.17 ***	1.45 *	94.24 **	197.82 ***
Δ SRE_GFEC	6.02 ***	3.48 **	84.02 **	154.15 ***	4.96 ***	0.98	65.75	163.46 ***
Δ SRE_FCT	6.52 ***	4.54 ***	88.17 ***	152.54 ***	6.89 ***	0.95	66.59	124.35 ***
Δ EGRS	2.57 *	0.12	56.18	106.42 ***	11.32 ***	1.28	87.65 **	147.14 ***
Δ FEC	7.41 ***	3.65 ***	99.78 ***	243.83 ***	4.84 ***	0.49	55.35	204.51 ***
Δ OLB	5.01 ***	2.21 *	32.61 *	76.55 ***	3.35 **	0.51	225.21	71.43 ***
Δ HYDRO	15.72 ***	8.81 ***	173.35 ***	308.51 ***	15.34 ***	3.84 ***	119.42 ***	280.43 ***
Δ GEO_THERMAL	474.95 ***	85.42 ***	91.43 ***	139.55 ***	317.56 ***	32.36 ***	76.25 ***	154.35 ***
Δ WIND	6.80 ***	4.88 ***	118.67 ***	243.53 **	11.43 ***	2.55 **	106.36 ***	247.79 ***
Δ ED	7.60 ***	7.74 ***	155.48 ***	357.62 ***	5.26 ***	2.73 **	107.62 ***	345.12 ***
Δ GGE	10.53 ***	6.94 ***	143.76 ***	244.04 ***	12.65 ***	3.81 ***	116.94 ***	258.40 ***
Δ PET	7.87 ***	4.86 ***	162.33 ***	177.42 ***	6.46 ***	0.91	82.32 *	144.72 ***
Δ RP	-6.67 ***	-4.63 ***	117.45 ***	253.43 ***	11.34 ***	2.94 **	104.43 ***	252.43 ***
Δ RD	-4.43 ***	2.88 ***	87.54 ***	178.45 ***	-3.99 ***	0.76 **	69.92 ***	169.65 ***
Δ LF	2.67 **	2.38 *	82.38 *	177.40 ***	3.48 **	1.34	76.86 *	236.36 ***

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

4.3. Estimations of Fixed Effects

Table 5 explains the case of the three proposed models. In model 1 variables PRE and GGE are significantly correlated with sustainable growth. In model 2, we included variable CRE and excluded the PRE variable that is positively associated with sustainable growth. Our third model shows that SRE_GFEC has a direct and major effect on growth. Table 6 shows the impact of hydropower, geothermal energy, and wind energy on sustainable economic development. The outcomes of this research show that in the case of Model 1, the variable HYDRO is insignificantly influencing sustainable growth. This implies that conserving the hydroelectricity by adopting the energy conservation policies in these countries will have no impact on economic growth. In Model 2, GEOTHERMAL is included, and it shows the direct and significant effect on sustainable growth. Our third model reveals the fact that variable WIND has a momentous influence on growth. Our empirical findings are consistent with those of Bulut and Inglesi-Lotz [12], Ewing and Sari [43], Bilgili and Kuşçaya [44], and Menegaki and Tugcu [45].

Table 5. Estimations of Fixed effects model.

Variables	Model1	Model 2	Model 3
PRE	0.08 *** (5.31)		
CRE		0.07 *** (4.19)	
SRE_GFEC			1.45 *** (5.28)
SRE_FCT			
EGRS			
FEC			
ED	0.12 (1.58)	0.15 (1.58)	0.11 (1.62)
GGE	0.26 * (2.42)	0.37 * (2.55)	0.51 *** (4.83)
PET	0.09 (0.71)	0.54 (0.96)	0.03 * (2.14)
RP	0.05 (0.29)	0.09 (0.19)	0.06 (0.82)
RD	5.63 * (2.42)	6.76 ** (2.35)	1.41 (0.84)
LF	0.62 (1.74)	0.52 (1.74)	0.19 (1.16)
Constants	13.95 *** (5.26)	12.34 *** (5.64)	4.97 * (2.53)
F statistic	8.72 ***	7.36 ***	7.64 ***
R-sq within	0.28	0.34	0.26
Observations	192	192	192
N Countries	8	8	8

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

Table 6. Estimation of Fixed-effects model regarding hydropower energy, geothermal energy, and wind energy sources on economic growth sustainability.

Variables	Model 1	Model 2	Model 3
HYDRO	0.05 (1.59)		
GEOTHERMAL		0.05 * (2.48)	
WIND			0.06 *** (9.58)
ED	0.13 * (2.58)	0.42 * (2.63)	0.25 * (2.31)
GGE	0.25 * (2.34)	0.28 ** (2.49)	0.53 *** (4.77)
PET	0.05 (1.34)	0.07 (1.57)	0.08 (0.95)
RP	0.02 (0.42)	0.08 (0.14)	0.00 (0.09)
RD	8.42 *** (3.94)	8.46 ** (3.53)	6.83 *** (3.75)
LF	0.01 (0.04)	0.08 (0.15)	0.05 (0.64)
Constants	8.44 *** (4.22)	8.50 *** (4.76)	6.61 *** (3.35)
F-statistic	5.07 ***	5.17 ***	23.92 ***
R-sq within	0.13	0.14	0.40
Observations	192	192	192
N Countries	8	8	8

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

Table 7 states the Kao test results. The Pedroni [29] test evaluates uniform cointegration relationships through pooled regression and considers each fixed effect. We used the ADF panel cointegration test to prove that the cointegration vector is consistent, and the test revealed cointegration between specific variables. Table 8 states the fisher test results

Table 7. Kao (Engle-Granger based) test results.

ADF (t-Statistic)	Residual Variance	HAC Variance
4.22 ***	0.001	0.002

Notes: *** $p < 0.001$. Akaike Info Criterion was selected for lag length.

Table 8. Fisher (combined Johansen) test results.

Hypothesized	Fisher Stat.	Fisher Stat.
No. of CE(s)	(From Trace Test)	(From Max-Eigen Test)
None	513.5 ***	483.5 ***
At most 1	126.3 ***	112.3 ***
At most 2	96.2 ***	94.5 ***

Note: *** $p < 0.001$.

The hypothesis of a long run correlation was confirmed. Next, we will evaluate this association for the panel pooled method. The results from Table 9 reveal the fact that a

1 percent increase of the power sources generates an increase of the total national output per capita by 0.07% (if “FMOLS” model is used for estimation) or 0.06% (if “DOLS” model is used for estimation). The Akaike information criterion was used to choose the lag length.

Table 9. The output of the panel fully modified OLS (FMOLS) and dynamic OLS (DOLS) models.

Variables	FMOLS	DOLS
PRE	0.07 *** (3.24)	0.06 *** (4.59)
ED	0.07 (1.36)	0.12 (1.59)
R-squared	0.99	0.99
Adjusted R-squared	0.90	0.95
S.E. of regression	0.06	0.05
Durbin-Watson stat	0.39	0.31
Mean dependent var	9.09	8.95
S.D. dependent var	0.72	0.74
Sum squared resid	1.62	1.85
Long-run variance	0.01	0.01

Notes: *** $p < 0.001$. Panel method: pooled.

In the essential sustainable energy power generation, we revealed a causal relationship between vitality dependence, and the per capita GNP using the “PVECM Granger causality” and the results are presented in Table 10. This table demonstrates the approximate post-effects assumptions for short- and long-term transport factors as shown by Equations (6)–(8). Schwarz information criterion revealed a two-lag model, as Equation (6) from Table 10 shows that the creation of sustainable sources of power has an insignificant impact on the total output of national per capita in the short term. Equation (7) shows that GDP per capita affects the important generation of maintainable power sources in the short run, and along these lines, the protection theory being upheld is comparable. Meanwhile Equation (8) essentially shows that the creation of sustainable power sources emphatically influences vitality reliance in the short run.

Table 10. Granger causality is based on the panel vector error correction model (PVECM).

Variables	Short-Run (or Weak) Granger Causality			Long-Run Granger Causality
	DGDPC	DPRE	DED	ECT
(6) Δ GDP	–	10.16 **	3.35	0.001
(7) Δ PRE	1.26	–	3.26	0.017 **
(8) Δ ED	1.94	4.25	–	0.013 ***

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

5. Conclusions

This study analyses the causality between renewable sources of energy and development of South Asian countries’ economies. This study uses data sets from different sources, such as WDI, ADB and different economic surveys. The outcomes of this study explain that in the case of Model 1, sustainable growth is not correlated to the variable hydro. In Model 2, geothermal energy is involved, and it showed a direct and significant effect on sustainable growth. The third model, the one that includes variable wind shows that the variable has a significant influence on the growth level. The results reveal that renewable energy sources show a momentous effect on the economic growth of South Asia. Besides this, environmentalists and energy exports have similar studies to get the views

of local communities. Moreover, the results of this study can be considered together to decide about energy policies for south Asian countries. They can provide useful information for the government representatives, energy exports, and utilities to design effective mechanisms, to charge an appropriate amount to support a greater portfolio to achieve their desired goals through the sources of renewable energy. This study supports the hypothesis that renewable energy sources have a significant impact on economic growth of SAARC economies.

Energy and growth are directly interrelated to each other in the process of production and they used as the main complement of the capital stock and input. In such circumstances, the policies regarding energy can significantly influence the growth level of the economy. According to this argument, the influence of energy on economic growth is very high and the policies based on conventional energy have been affected by the level of economic growth. In our study we showed that the energy Granger causes economic growth, thus energy protection policies have an important impact on the level of GDP growth. The developed and developing countries' panel data analyses have been supported by various empirical analysis. The income of the economy is influenced by intensive policies of energy or conservation policies of energy in any country in the South Asian region.

We have identified several policy implications based on the results of our research. First, we suggest that policymakers of Asian countries' governments should continue the policies relating to the provision of incentives in the form of tax deductions, subsidies, etc. so that renewable sources of energy become more attractive for business as their economic impact in the long term, both on the economy and government policies regarding the promotion of alternate energy sources, cannot be ignored. Second, the findings of our research enforce the importance of renewable sources of energy as it can be deduced that such sources not only ease the pressure on policymakers regarding the improvement in the environment, but would also improve the economic growth of the Asian economy.

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