Energy Strategy Reviews 29 (2020) 100484

Contents lists available at ScienceDirect

Energy Strategy Reviews

journal homepage: http://www.elsevier.com/locate/esr

# Renewable energy, institutional stability, environment and economic growth nexus of D-8 countries

Mahjabeen [a,*], Syed Z.A. Shah [a], Sumayya Chughtai [a], Biagio Simonetti [b,c,d]

[a] International Islamic University, Islamabad, Pakistan
[b] University of Sannio, Benevento, Italy
[c] WSB University, Gdansk, Poland
[d] National Institute of Geophysics and Volcanology (INGV), Naples, Italy

ARTICLE INFO

*Keywords:*
Renewable energy
Non-renewable energy
Institutional quality
Economic output
Environment quality
D-8 countries

ABSTRACT

The anthropogenic impact of conventional energy sources encourages the utilization of renewable energy, as it has become a strategic commodity for economic growth. On the other hand, institutional stability is the pre-requisite without which environmental quality cannot be assured and the economy cannot function. However, in recent literature, very little consideration has been given to this important phenomenon. This study is set to analyze the energy-institutional stability-economic growth nexus, as well as the energy-institutional stability-environmental quality nexus, by incorporating the Cobb Douglas production function and the Diet and Rosa environmental function respectively. The sample consists of the D-8 countries and the time period spans 1990 to 2016. To analyze the developed models, Autoregressive Distributive Lag (ARDL), Fully Modified Ordinary Least Square (FMOLS) and Dynamic Ordinary Least Square (DOLS) tests are applied, along with other econometric techniques. The panel ARDL statistics indicate significant cointegration among all variables of both functions, while the FMOLS test reveals that consumption of both nonrenewable and renewable energy has a positive impact on economic growth, as well as on environmental degradation. Further, results indicate that institutional stability is crucial for establishing a nation on a sound footing and protecting environmental quality. Based on these results, the study suggests a blend of both types of energy and a gradual transition toward renewable energy sources, with better implementation of policies and technological advances, to produce, preserve, and transmit renewable energy production.

## 1. Introduction

Environmental degradation and greenhouse gas emissions are the new challenges for the new millennium. Rapid economic growth poses a serious threat to mankind, in the form of resource depletion, pollution, and climate change. To deal with these challenges, the UNFCCC (United Nations Framework Convention on Climate Change) has established a basic framework for global cooperation on this very issue; in addition, the 2030 Agenda, Kyoto Protocols (1997) and Copenhagen Accords (2009) are deterministic steps to deal with the issue of deteriorating environmental quality. Energy consumption is the pre-requisite of economic growth and considered the fundamental aspect of economic growth. Around the world, the dominant source of energy is fossil fuels, also called conventional energy sources. Almost 85% of cumulative energy needs are fulfilled by fossil fuels, which also account for 56.6% of the emissions of greenhouse gasses ($CO_2$ equivalent) [1]. In the coming era of economic and environmental compatibility, the anthropogenic emission of greenhouse gases should be reduced to overcome and mitigate catastrophic environmental degradation and climate change [2]. Therefore, a transition to cleaner energy is the ultimate challenge for economies, to ensure energy security, reduce environmental degradation, and spur economic growth [3–6].

Renewable energy is considered a strategic commodity and one of the basic indicators of economic growth and sustainable development [7]. Renewable energy sources are mainly solar (photovoltaic), wind, tidal, waste and biomass, which are considered eco-friendly and cost-effective, as they reduce harmful climate change, mitigate pollution, provide energy security, and help alleviate poverty by providing electricity to remote areas due to their decentralized nature [8–10]. A wide range of studies have analyzed the impact of renewable and

* Corresponding author.
*E-mail address:* Mahjabeen_88@hotmail.com (Mahjabeen).

https://doi.org/10.1016/j.esr.2020.100484
Received 4 May 2019; Received in revised form 27 February 2020; Accepted 18 March 2020

non-renewable energy on economic output and carbon emissions; most of these studies have shown a negative association of renewable energy sources with carbon emissions [11–13] and a positive association with economic output [13–15] but, still, the findings on the potential of renewable energy to reduce environmental pollution and enhance sustainable development are mixed [12]. Some studies also demonstrate no differential effect of renewable and nonrenewable energy production and consumption on carbon emissions [16–18]. Similarly, research shows that renewable energy has a positive association with the environment when it reaches a certain minimum threshold level. The negative effects of renewable energy on environmental quality are mostly caused by a lack of technology, storage quality, as well as poor transmission systems [19]. Therefore, to increase sustainable development, the negative environmental impact of renewable energy consumption can be controlled by technological advances and proper transmission systems [9,20–22].

Developing countries face multifaceted energy challenges. They are expanding their economic activities with a parallel increase in demand for energy that is mostly met by conventional sources. These conventional energy sources (gas, coal, oil, etc.) are being depleted gradually and their prices are very volatile. As developing countries are net importers of these conventional sources, they are affected adversely by price fluctuations. These countries are also characterized by low institutional quality and long procedural delays, as well as unpredictable investment needs due to corruption and hierarchical interference [23]. Governmental responsiveness to the population's concern is the main contributing factor that can lead a nation to economic and social development, but developing countries have low political stability and poor democratic quality. Research indicates that economic growth is higher in democratic states than autocratic states [14] because, in a high-quality political regime, energy consumption has a greater impact on economic growth [24], and the effect different macroeconomic factors have on environmental quality depends on institutional quality [25]. But the phenomenon of institutional stability in the context of environmental quality and economic growth is still understudied and needs to be further explored [14,24].

Based on the above explanations, this study's sample comprises the D-8 or developing eight countries, to analyze how different economic factors, specifically renewable and nonrenewable energy consumption, institutional stability, and other macroeconomic factors, affect economic growth and environmental quality in these countries. To analyze the energy-institutional stability-economic growth nexus, the Cobb–Douglas production function is applied to avoid the errors of omitted variables and model specification [26,27]. The Cobb–Douglas production function is widely used to express the relation of output to input [13,28] and considered as the modern perspective of economic growth [26]. This study incorporates economic activity as the output of various production factors: renewable and nonrenewable energy consumption, capital, labor, and institutional stability. Further, to analyze the energy-institutional stability-environment nexus, Diet and Rosa's environmental function [29] is incorporated. This model particularly measures the effect of population, affluence and environmentally damaging technology and has been further modified and adopted by many researchers [30]. This study has adopted the modified version of the model [13] to analyze the impact of renewable and nonrenewable energy consumption, affluence, population, and institutional stability on environmental quality.

This study makes significant contributions to the literature: first, though there is an expanding literature on the energy-economic-environmental nexus, D-8 countries have rarely been targeted before. Empirical findings can vary substantially among different groups of countries, even for the same country, due to the different economic situations and chosen time periods [7,27]. So, this study will increase understanding of the sampled countries' economies and environmental conditions. Secondly, by employing the Cobb–Douglas production function and Diet and Rosa's environmental function, the study also makes use of traditional factors, along with some very important input factors, e.g. democracy index as an indicator of institutional stability. Political and institutional quality plays a significant role in improving environmental quality and enhancing economic growth [12,31]. We argue that sustainable development is associated with institutional stability, but only a few studies have highlighted its impact on sustainable development [26]. So, this study highlights the role of institutions as the main input factor for environmental well-being and economic output. Thirdly, this study adds to the ongoing debate on the usability of renewable and nonrenewable energy sources, by presenting a holistic view of the possible impact of explanatory variables on both economic activity and the environment. Lastly, the study has employed different econometric techniques of panel data, e.g. FMOLS, DOLS, ARDL, etc., and hence offers useful policy implications for the D-8 countries, considering the economic situation and inferential results.

The next section describes the D-8 countries, followed by a literature review, specifically on the association of renewable energy, economic growth, and the environment. The following section contains the data sources and methodology, followed by results, discussion, conclusion, limitations, and policy implications.

### *1.1. Insight into the Developing-8 countries' energy positions*

More than two decades ago, in 1997, eight Muslim countries (Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan, and Turkey), also called the D-8 (Developing 8), made a multilateral agreement with special emphasis on economic cooperation. The member countries are considered the fastest growing countries and have huge potential for economic development, thus their consumption of energy and electricity is also growing. The per capita electricity consumption of the D-8 countries is 1031 kWh, which is well below the other non-OIC (Organization of Islamic Cooperation) countries, that have an average consumption of 2202 kWh per capita [32]. Only Pakistan and Turkey have a 30% share of renewable energy in their total energy production, while the rest of the countries produce over 90% of their energy from fossil fuel sources. Besides this, only Iran and Pakistan possess the ability to produce energy from nuclear sources [32] and all other member countries rely mainly on conventional sources of energy production. The working committee on renewable energy[1] (WCRE) has been established for proper planning and implementation of strategies to spread awareness and to take measures to increase the share of renewable energy sources. Fig. 1 presents energy production and consumption in the D-8 countries, showing their high reliance on conventional energy sources. These countries are best suited for analysis, as they are all facing the above-mentioned problems of conventional energy usage, growing economies and uneven institutional quality.

## 2. Literature review

Production processes and modernization depend heavily on energy because sustainable economic growth cannot be achieved without an uninterrupted energy supply. Renewable energy sources are considered the best alternative to conventional sources, while a hybrid energy system is considered to be the ultimate solution, especially for rural electrification [28]. Considering the importance of renewable energy, many authors have endeavored to discover its impact on economic actives which can be classified into four types of conclusion or hypothesis.

Since the pioneering study by Kraft and Kraft [33], the energy-economic nexus has been broadly studied by researchers. Generally, the association of energy consumption and economic growth fall into four types of hypotheses, each of which posits implications for policy-making [13,26,27]. The first one is the growth hypothesis that subsumes unidirectional causality from energy towards economic

[1] http://developing8.org/areas-of-cooperation/renewable-energy/.

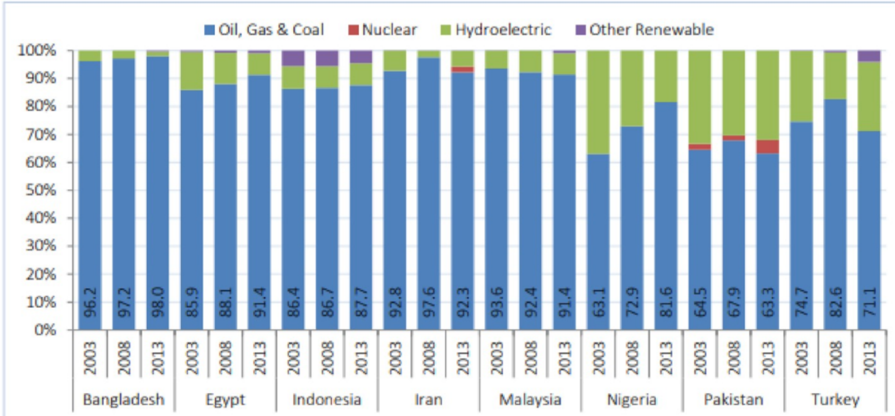


**Fig. 1.** Energy production by source (top) and consumption (bottom) of the D-8 countries (source: D8 economic outlook 2016-17).

activities. It means the higher the energy consumption, the higher the economic growth, hence, energy-saving measures and policies can have contradictory effects on economic activities. The second one is the feedback hypothesis, which is valid when there is a bidirectional relationship between energy consumption and economic growth. It means that economic growth and energy consumption affect each other and have a mutual association. The third hypothesis is the conservation hypothesis that asserts unidirectional causality from economic growth towards energy consumption. This hypothesis prevails when economic growth has a positive impact on energy consumption, while energy conservation measures and policies do not affect GDP. The last hypothesis is the neutrality hypothesis that implies no causal association between energy consumption and economic growth; so, the results of previous studies comprise these findings and have found evidence of all these hypotheses. Below we will discuss the literature, specifically on renewable energy consumption and economic growth, and, in the next subsection, studies on renewable energy and the environment are reviewed.

### *2.1. Renewable energy consumption, economic growth and institutional stability*

One of the earliest studies on the causality of renewable energy and economic growth was carried out by Chein and Hu [34], when they asserted that increased renewable energy has a positive association with economic efficiency, while increased consumption of conventional energy sources leads to decreased overall economic efficiency. In a recent study, Paramati, Sinha and Dogan [13] analyzed the role of renewable energy on economic activates and $CO_2$ emissions for the developing countries; using data from 19901 to 2012, they concluded that renewable energy has a positive and significant association with economic growth, while having a negative and adverse effect on $CO_2$ emissions, hence they advocated employing more renewable energy in the current grid system to pace economic growth and to save the environment from degradation. Similarly, the same notion is adopted by Ref. [26], where the authors studied the impact of renewable energy consumption on GDP for Turkey for the period from 1990 to 2015. They found renewable energy did not affect GDP and asserted that the proportion of renewable energy was too small to have a significant impact on GDP. They further suggested increasing the share of renewable energy to decrease the deficit of energy trade. Contrary to these findings, another study analyzed the same notion for the same country and found a unidirectional causality between renewable energy and economic growth, while an autoregressive distributive lag (ARDL) test showed the negative association between renewable energy and economic growth [27]. Another important study on the association between renewable energy and economic development was conducted using quarterly data from 1972 to 2011. It demonstrated that renewable energy has a feedback effect with economic growth, while the rest of the variables have a long-term association with each other [28]. While analyzing the energy scenario of Pakistan, another study found that energy consumption and economic growth have bidirectional causality; at the same time, energy consumption leads to environmental degradation [20]. So a sufficient proportion of energy sources should be renewable to enable smooth economic growth without compromising the environment. Apergis and Payne [15] analyzed the relationship between renewable energy consumption and economic growth in the countries of Eurasia from 1992 to 2007. The result of the heterogeneous panel co-integration test reveals the long-term equilibrium between real GDP, capital formation, labor, and renewable energy consumption. The error correction model indicated a bidirectional association between economic growth and renewable energy consumption for the short and long-term periods. Most developing countries are rich in biogases, which are an important component of renewable energy. Developing countries can enhance the installed capacity of biogases to optimize their potential contribution in the energy mix [35]. In another study [7], of the Middle East and North Africa (MENA), net oil importing countries, results show a bi-directional causality between both kinds of energy source and economic growth, as well as between renewable and nonrenewable energy consumption that highlights their substitutability and interdependency. The results indicate that both types of energy source are essential for economic growth. Along with energy sources, the study also incorporated the regime type to analyze its impact on economic development for the of Sub-Saharan Africa for the period of 1980–2012 and found a long-term association between variables. Specifically, both sources are found to be significant for economic development, while nonrenewable energy is more salient for economic growth. Importantly, it was found that autocratic countries have less economic growth than democratic states.

The role of political stability, regime type, and democracy cannot be ignored in the energy-economic growth nexus. Using data from 16 Sub-Saharan countries, Adams et al. [24] analyzed the role of regime type and energy consumption along with trade openness on economic growth. Their results confirm that democracy moderates the relationship between energy consumption and economic growth. Adams et al. [14] analyzed the impact of renewable and non-renewable energy regime type on economic growth for 30 Sub-Saharan countries for the period of 1980–2012. The results of various tests indicate a long-term association among variables and that the growth rate of democratic countries is higher than in autocratic countries. Therefore, most of the previous studies have been done in bits and pieces, and the role of institutional stability in economic growth is understudied. The present study addresses the issue and applies the production function to analyze the energy-institutional stability-economic growth nexus.

### 2.2. Renewable energy consumption, environmental quality and institutional stability

Renewable energy has a significant role in controlling environmental degradation and energy transition [36]. The causality between energy consumption and environmental degradation has been the subject of intensive studies for the last two decades, with particular emphasis on renewable energy. The literature covers a wide range of geographical locations, a number of explanatory variables and a variety of econometric tools. In the next section, we will discuss these studies.

One of the earlier studies on the association between renewable energy and environmental degradation was conducted by Sadorsky [37], who analyzed the causal relationship for 18 emerging countries for the period from 1994 to 2003, conducting Granger causality and Padroni co-integration tests. The results supported the neutrality hypothesis in the short term and conservation hypothesis in the long run. In another study by Apergis and Payne [38], determinants of renewable energy for the 25 OECD (Organization of Economic Cooperation and Development) countries for the time span of 1980–2011 were analyzed. Results of the co-integration and error correction model tests showed the long-term relationships between renewable energy consumption, $CO_2$ emissions and the rest of the variables, while they also found the evidence of feedback hypothesis. Similarly, the association between renewable energy, environmental degradation and economic growth has been analyzed for the period of 1975–2008 in 12 MENA countries [39]. Applying the panel co-integration test, results showed evidence of the conservation hypothesis in the long run and the growth hypothesis in the short term. By adding trade openness to the explanatory variables of the production function, the association between economic output, renewable energy and $CO_2$ emissions for the BRICS (Brazil, Russia, India, China and South Africa) countries for the period of 1971–2010 was analyzed [40]. The results of the bound ARDL test reveal the conservation hypothesis for India and South Africa. The Environmental Kuznets Curve hypothesis was examined by incorporating renewable and nonrenewable energy consumption as explanatory variables for the time span of 1970–2012 [41]. The result of this study confirmed bidirectional causality between renewable energy consumption and $CO_2$ emissions, as well as non-renewable energy consumption and $CO_2$ emissions. Further, the researchers found a significant negative association between renewable energy consumption and $CO_2$ emissions and a positive association between non-renewable energy consumption and environmental degradation. In another study [42], the SAARC (South Asian Association of Regional Cooperation) countries were analyzed to find possible associations among renewable energy consumption, poverty, GDP and natural resource depletion. The results of the FMOLS (Fully Modified Ordinary Least Square) approach showed a significant association, while the causality test confirms the growth hypothesis between variables.

According to Sarkodie and Adams [12], institutional quality plays a significant role in maintaining environmental quality and energy regulations. For their regional study of South Africa, they employed ARDL with a structural break cumulative sum test and results reveal that the Environmental Kuznets Curve hypothesis holds in South Africa and that diversification of the energy portfolio through renewable energy is required to reduce air pollution and vulnerability to energy price changes. In the energy-economic-environment nexus, Bekun, Alola and Sarkodie [43] added the natural resource rent and results of the pooled mean group ARDL suggest a positive association between resource rent and carbon emissions in the long run. The causality analysis depicts a feedback mechanism between economic growth, renewable and nonrenewable energy. Dong, Sun and Hochman [44] advocate the consumption of natural gas and renewable energy for environmental sustainability and their analysis confirms the Environmental Kuznets Curve hypothesis for the BRICS countries. Further, the causality analysis explains the feedback mechanism among natural gas, renewable energy consumption, and economic growth. By employing the latest methodology and allowing for cross-section dependence and slope heterogeneity, key impact factors for carbon emission are analyzed by Ref. [45] by including a large sample of 128 countries; overall results indicate a negative association of renewable energy and carbon emission. Controlling for the effect of the ecological footprint, Saint Akadiri, Bekun and Sarkodie [46] analyzed the impact of energy consumption and GDP per capita on environmental quality in South Africa. Results indicate that pollution and environmental degradation is not output-driven but depends on energy consumption and production. Using an unbalanced panel of 128 countries, Dong et al. [11] analyzed the impact of renewable energy, population and economic growth on $CO_2$ emissions. Considering the slope heterogeneity and cross-sectional dependence, the authors employed the common correlated effect mean group, whose results indicate that population and economic growth have a significant positive influence on carbon emissions, both at a global and regional level. Similarly, a study by Sarkodie and Strezov [47] shows that the Environmental Kuznets Curve hypothesis holds in Australia. Proposing a transition from energy-intensive industries to less carbon-intensive industries, the results of DOLS (Dynamic Ordinary Least Square) and FMOLS indicate that disaggregated energy sources, along with energy imports and exports, have a positive influence on the ecological footprint and carbon emissions in Australia.

Contrary to the above findings, some studies, however, show that there is no differential effect of renewable and nonrenewable energy on carbon emission and pollution. The study by Farhani and Shahbaz [16] analyzed the impact of renewable and nonrenewable energy consumption on $CO_2$ emissions for MENA countries. The results of DOLS and FMOLS show that both kinds of energy contribute to $CO_2$ emissions. Similarly, the study by Bilgili, Koçak and Bulut [18] researches the same concept by analyzing the 17 OECD countries for the period from 1997 to 2010. Another study [17] analyzed data from 16 European countries for the period 1990–2008. The results of ordinary least square (OLS) and fixed effect reveal that both kinds of energy contribute to greenhouse gas emissions; however, renewable energy contributes less than nonrenewable energy. Further, the authors state that renewable energy has a positive association with the environment when it reaches a certain minimum threshold. The reason for the contribution to environmental degradation is the lack of production and storage quality and technology

**Table 1**
Data sources and description.

| Code | Variable name | source |
|---|---|---|
| $CO_2E$ | Carbon Dioxide Emission = Metric Tons Per Capita | WDI, EDGAR |
| Y (GDP) | Gross Domestic Product Per Capita | WDI |
| IS | Institutional stability = average for political rights and civil liberty (1–7) | Freedom House |
| NREC | Non-renewable energy consumption = kilo ton of oil equivalent | WDI |
| REC | Renewable energy consumption = % share of renewable energy in total energy consumption | WDI |
| K | Capital formation = gross fixed capital formation % of GDP | WDI |
| L | Labor = total employment from the age of 15+ | WDI |
| PI | Per capita income | WDI |
| POPG | Population growth annually | WDI |

Note: WDI= World Development Indicator, EDGAR = Emission Database on Global Atmosphere.

as well as poor transmission systems [19]. So the negative effect of renewable energy can be controlled by proper management and transmission technology in the grid system.

The role of institutions and economic freedom is taking a stance in resource management literature. Al-Mulali and Ozturk [48] analyzed the influence of political stability on environmental quality, along with energy consumption, trade openness, urbanization and the ecological footprint for 14 MENA countries. By employing FMOLS, the authors found that political stability plays an important role in controlling environmental quality. Similarly, another study [3] added economic freedom to the energy-growth-environment nexus for 85 developed and developing countries. The results of FMOLS indicate that the role of institutions, as well as renewable energy, have a significant positive impact on economic growth and environmental quality. According to Adams and Klobodu [31], democracy and bureaucratic quality are the main determinants of environmental quality.

In a nutshell, the findings on the potential contribution of renewable energy to environmental quality are not clear. Furthermore, there is scant literature on the possible impact of institutional stability and quality in environmental maintenance. The present study fills this gap by employing the Diet and Rosa environmental function to analyze the energy-institutional stability-environment nexus.

## 3. Methods and material

The main objectives of the present study are to analyze both the renewable energy-institutional stability-economic growth nexus and the renewable energy-institutional stability-environmental quality nexus of the D-8 countries. The panel dataset is constructed using the time span from 1990 to 2016 (27 observations per cross-section). To analyze the economic growth nexus, this study has employed the modified Cobb–Douglas production function, where the impact of the different input variables is analyzed on the economic activity of the D-8 countries. Following previous studies, this one has used nonrenewable energy consumption in the model as a comparison with renewable energy consumption. Furthermore, we cannot exclude conventional energy sources from the model to avoid the bias and error of omitted variables, as previous studies have shown a significant association of fossil fuel energy with economic output and environmental quality.

After adding parameters, the equation form is

$$Y = \alpha + \beta_1(K_{it}) + B_2(L_{it}) + \beta_3(NREC_{it}) + \beta_4(REC_{it}) + B_5(IS_{it}) + \varepsilon \tag{1}$$

Table 1 contains details of the variables along with measurement units and data sources. The data is measured in different units, which can cause problems associated with the distributional properties of the data series [13], so, following the previous literature, all the variables are transformed into a natural logarithm. The log-linear production function is

$$\ln Y = \alpha + \beta_1(lnK_{it}) + B_2(lnL_{it}) + \beta_3(lnNREC_{it}) + \beta_4(RlnREC_{it}) + B_5(InIS_{it}) + \varepsilon \tag{2}$$

To analyze the renewable-institutional stability-environmental quality nexus, Diet and Rosa's environmental function is adopted. The model, originally developed by Rosa [29], has been subject to development and changes, and many authors have added different parameters according to their study objectives, along with the basic parameters e.g. population, per capita income, and affluence technology. In this study, the model modified by Paramati, Sinha and Dogan [13] is adopted and a measure of institutional stability is added to the equation.

$$CO_2E = f(POPG\ PI\ IS\ REC\ NREC)$$

After adding the parameters, the equation form is

$$\mathrm{CO_2E} = \alpha + \beta_1(PI_{it}) + \beta_2(POPG_{it}) + \beta_3(NREC_{it}) + \beta_4(REC_{it}) + \beta_5(IS_{it}) + \varepsilon \tag{3}$$

To overcome the distribution properties of data series, all variables are transformed into a natural logarithm. The log-linear equation for the study is

$$\mathrm{lnCO_2}E = \alpha + \beta_1(lnPI_{it}) + \beta_2(lnPOPG_{it}) + \beta_3(lnNREC_{it}) + \beta_4(lnREC_{it}) + \beta_5(lnIS_{it}) + \varepsilon \tag{4}$$

The study has employed ARDL estimation for co-integration as it has many advantages over other co-integration techniques. ARDL estimation gives rigorous results for a small sample and allows multiple predictors to have different lag orders [12]. Based on ARDL estimation, the empirical specification of equations (3) and (4) is:

$$\Delta \mathrm{lnY_t} = \alpha_0 + \delta_1 \mathrm{Yt} - 1 + \delta_2 \ln K_{t-1} + \delta_3 \ln L_{t-1} + \delta_4 \ln NREC_{t-1} + \delta_5 \ln REC_{t-1} + \delta_6 \ln IS_{t-1} + \sum_{i=1}^{p} \beta 1j \Delta \mathrm{Y} - \mathrm{i} + \sum_{i=0}^{p} \beta 2j \Delta lnKt - i + \sum_{i=0}^{p} \beta 3j \Delta lnLt - i + \sum_{i=0}^{p} \beta 4j \Delta lnNRECt - i + \sum_{i=0}^{p} \beta 5j \Delta lnRECt - i + \sum_{i=0}^{p} \beta 6j \Delta lnISt - i + \varepsilon t \tag{5}$$

$$\Delta \mathrm{lnCO2t} = \alpha_0 + \delta_1 \mathrm{CO2t} - 1 + \delta_2 \ln PI_{t-1} + \delta_3 \ln POPG_{t-1} + \delta_4 \ln NREC_{t-1} + \delta_5 \ln REC_{t-1} + \delta_6 \ln ISt - 1 + \sum_{i=1}^{p} \beta 1j \Delta \mathrm{CO2t} - \mathrm{i} + \sum_{i=0}^{p} \beta 2j \Delta lnPIt - 1 + \sum_{i=0}^{p} \beta 3j \Delta lnPOPGt - 1 + \sum_{i=0}^{p} \beta 4j \Delta lnNRECt - 1 + \sum_{i=0}^{p} \beta 5j \Delta lnRECt - 1 + \sum_{i=0}^{p} \beta 6j \Delta lnISt - 1 + \varepsilon t \tag{6}$$

The first model of the study pertains to capital, labor, technology as a traditional factor of production, along with renewable and nonrenewable energy consumption and democracy index (institutional stability).

The initial production function is

$$\mathrm{Y} = f(KLT)$$

The modified production function for the study is

$$\mathrm{Y = f(K\ L\ IS\ REC\ NREC)}$$

where $\mathrm{lnCO_2E}$, ln, lnPI, lnPOPG, lnK, lnL, lnNREC, lnREC, lnIS indicate natural log forms of carbon dioxide emission, economic growth, per capita income, population growth, capital formation, labor employed, nonrenewable energy consumption, renewable energy consumption, and institutional stability measured as the average of civil liberty and

**Table 2**
Descriptive statistics and correlation matrix of D-8 countries.

| | MEAN | SD | LNIS | LNREC | LNNREC | LNPOP | LNPI | LNK | LNL | LNGDP | LNCO2E |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LNIS | 1.49228 | 0.25722 | 1 | | | | | | | | |
| LNREC | 8.85905 | 1.50054 | −0.44668 | 1 | | | | | | | |
| LNNREC | 4.15913 | 0.57359 | 0.08275 | −0.68494 | 1 | | | | | | |
| LNPOPG | 0.63319 | 0.34364 | 0.13043 | 0.22070 | −0.69633 | 1 | | | | | |
| LNPI | 7.63854 | 1.04561 | −0.05602 | 0.18233 | −0.04892 | 0.05938 | 1 | | | | |
| LNK | 3.03774 | 0.38800 | −0.10176 | −0.32104 | 0.73951 | −0.68791 | 0.00282 | 1 | | | |
| LNL | 3.79550 | 0.34795 | −0.26260 | −0.31193 | 0.71621 | −0.61083 | −0.33963 | 0.66085 | 1 | | |
| LNGDP | 25.67461 | 1.51152 | −0.10897 | −0.35996 | 0.85908 | −0.83766 | 0.02098 | 0.72596 | 0.74674 | 1 | |
| $LNCO_2E$ | 0.45466 | 1.10431 | 0.22101 | −0.43778 | 0.63446 | −0.40407 | 0.60558 | 0.49079 | 0.22797 | 0.61612 | 1 |

political rights [26] respectively. α denotes the intercept, Δ is the first difference operator, p is the lag order, β and δ denote the slope coefficient, ε is a stochastic term.

## 4. Results and discussion

The empirical testing of the study begins with descriptive statistics and the correlation matrix. Table 2 presents the correlation matrix and the descriptive statistics of all the variables. The descriptive statistics indicate that there are no outliers in the data and the data is stable. The correlation matrix indicates that some independent variables have a high correlation but, in the panel data analysis, the number of observations is greater than the time series analysis, which reduces the concern of multicollinearity [49]. There is a strong and positive correlation (0.859081) between GDP and renewable energy consumption; on the other hand, the correlation between nonrenewable energy consumption and GDP is −0.35996. For carbon emissions, renewable energy has a negative (−0.43778) correlation with environmental degradation, indicating the opposite direction of variables, whereas nonrenewable energy has a positive correlation (0.634464).

The examination of the order of the variables is the most important step before applying any other econometric tools because it determines the selection of models for empirical analysis. To estimate the distributional properties of the variables, four different panel unit root tests are examined, where the Lavin-Lin-Chu (LLC) test is used to examine the common unit test while the individual unit-roots are analyzed by the Augmented Dicky-Fuller (ADF), Im-Pesaran-Shin (IPS) and Philips-Perron(PP) tets. The analysis of the integration and application of these tests is very important, e.g. if results confirm the stationary at I (1), they indicate that all the variables are stationary at first difference or first-order differentials and not stationary at a level so the variables might cointegrate as a group in the long run. Table 3 presents the results of the unit root test that indicates some of the variables are stationary at the level and others are stationary at first difference. Institutional stability and nonrenewable energy are stationary at a level while the rest of the variables are stationary at first difference. A decision was made regarding the significance of majority results, i.e., if three out of four tests indicate stationarity at the level, then the variable would be considered as stationary at level. The same is the case for the first difference. It is important to note that none of the variables are stationary at second difference 1(2), which leads to the estimation of the ARDL cointegration bound testing.

The autoregressive distributed lag (ARDL) approach of cointegration developed by Ref. [50] is employed in this study, as this econometric tool is widely used [13,27,28] and has many advantages over other cointegration tools, e.g. Johansen and Juselius. Other cointegration tools use more than one equation in establishing long-term parameters while ARDL uses one equation. This approach can also be used whether the variables are stationary at the level or at first-order [26]. It also avoids the endogeneity problem and serial correlation and, finally, it is most suitable for small samples. The ARDL test was followed by a Wald test to determine the robustness of the estimates through the F-statistics. The null hypothesis for the Wald test assumes no cointegration among the parameters ($\beta1 = \beta2 = \beta3 = \beta4 = \beta5 = 0$) while the alternative hypothesis assumes cointegration among variables ($\beta1 \neq \beta2 \neq \beta3 \neq \beta4 \neq \beta5 \neq 0$). The short-term results of the ARDL tests are presented in Table 4 for both models. The Akaike info criterion (AIC) is selected with a "constant trend" option, while the optimal lag length for economic output function is one and, for the environment function, the lag length is 2. The results for the environmental function indicate that all the variables have a significant association with their dependent variables; population growth contributes negatively to environmental degradation so that a 1% increase in population results in a 1.445% decrease in environmental quality. Particularly, renewable energy has a negative

**Table 3**
Testing the stationarity of the variables.

| Variables | LLC | | IPS | | ADF | | PP | | Decision |
|---|---|---|---|---|---|---|---|---|---|
| | 1(0) | 1(1) | 1(0) | 1(1) | 1(0) | 1(1) | 1(0) | 1(1) | |
| **$LNCO_2E$** | −2.1798 | −6.5124 | 0.26136 | 6.77555 | 11.6462 | 75.0730 | 13.0309 | 151.610 | 1(1) |
| | (0.0146) | 0.0000 | (0.6031) | 0.0000 | −0.7680 | 0.0000 | −0.6705 | 0.0000 | |
| **LNGDP** | 2.42662 (0.9924 | −2.33925 | 5.72021 | 4.79507 | 2.41804 | 54.2891 | 6.02684 | 102.699 | 1(1) |
| | | (0.0097) | (1.0000) | (0.0000) | (1.0000) | (0.0000) | (0.9878) | (0.0000) | |
| **LNIS** | −1.0159 | −5.44871 | −2.14484 | 7.07762 | 29.3938 | 78.7041 | 30.3527 | 119.682 | 1(0) |
| | (0.1548) | (0.0000) | (0.0160) | (0.0000) | −0.0214 | (0.0000) | (0.0163) | (0.0000) | |
| **LNNREC** | −4.0739 | −6.2060 | −1.9925 | −6.1070 | 29.9875 | 66.7509 | 45.8559 | 45.8559 | 1(0) |
| | 0.0000 | (0.0000) | −0.0232 | (0.0000) | −0.0181 | (0.0000) | (0.0001) | (0.0001) | |
| **LNREC** | −0.8871 | −5.4370 | 1.8666 | −5.5890 | 7.4383 | 61.0456 | 7.1538 | 109.5280 | 1(1) |
| | −0.1875 | 0.0000 | −0.9690 | 0.0000 | (0.9639) | (0.0000) | (0.9702) | (0.0000) | |
| **LNK** | −1.72404 | −6.6695 | −0.5293 | −6.4174 | 14.1433 | 70.5948 | 16.1385 | 91.9635 | 1(1) |
| | (0.0424) | (0.0000) | (0.2983) | (0.0000) | −0.5880 | (0.0000) | (0.4433) | (0.0000) | |
| **LNL** | 3.9568 | 9.1130 | 0.62870 | −3.7782 | 11.5108 | 44.7561 | 24.4403 | 85.2033 | 1(1) |
| | −1.0000 | −1.0000 | (0.7352) | −0.0001 | (0.7769) | −0.0002 | −0.0803 | 0.0000 | |
| **LNPI** | 0.61523 | −4.4405 | 2.76075 | −5.1930 | 4.66816 | 56.9754 | 3.1595 | 90.0874 | 1(1) |
| | (−0.7308) | (0.0000) | (−0.9971) | (0.0000) | (0.9972) | (0.0000) | (0.9998) | (0.0000) | |
| **LNPOPG** | 0.32566 | −3.0715 | 0.60691 | −5.2828 | 14.2645 | 63.7080 | 39.9819 | 22.1500 | 1(1) |
| | (0.6277) | −0.0011 | −0.7280 | (0.0000) | −0.5790 | 0.0000 | (0.0008) | (0.1384) | |

**Table 4**
Short term estimate of ARDL test.

| $CO_2E$ = f(POPG PI DI REC NREC) | | | | Y = f(K L DI REC NREC) | | | |
|---|---|---|---|---|---|---|---|
| Variables | Coefficient | T-Stat | Sig | Variables | Coefficient | T-Stat | Sig |
| LNPOPG | −1.445118 | −5.21328 | 0.0000 | LNIS | −0.232521 | −3.257713 | 0.0014 |
| LNIS | 0.253302 | 2.61238 | 0.0103 | LNK | 0.280819 | 3.174422 | 0.0018 |
| LNNREC | −2.761693 | −3.48599 | 0.0007 | LNL | 0.686186 | 2.639437 | 0.0092 |
| LNPI | 0.645139 | 8.58696 | 0.0000 | LNNREC | 7.092142 | 13.64693 | 0.0000 |
| LNREC | −0.590357 | −2.26751 | 0.0254 | LNREC | 1.207882 | 11.85181 | 0.0000 |
| AIC = −2.717660, Schwarz criterion = −1.01439 | | | | AIC = −4.38704, Schwarz criterion = −3.433836 | | | |
| Wald test statistics | | | | Wald test statistics | | | |
| F-statistic = 134.6705, p value = 0.0000 | | | | F-statistic = 384.6973, p value = 0.0000 | | | |
| Chi-square = 673.3525, p value = 0.0000 | | | | Chi-square = 1923.487, p value = 0.0000 | | | |

association with $CO_2$ emissions, which has important implications for policymakers. Interestingly, nonrenewable energy consumption has an inverse relationship with $CO_2$ emissions; on the other hand, per capita income and democracy index have positive associations. All parameters have a positive association with economic output, which implies the positive contribution of disaggregated energy sources and other production factors. The institutional stability measure, however, shows a significant but negative correlation with economic activity. Previously, Bulut and Muratoglu [26] found this variable had a negative but insignificant impact on Turkish economic activity. We can interpret this finding as a lower institutional stability index showing high stability, so high stability has a positive relationship with economic activity. The Wald test statistics showed a significant probability (0.000) F-statistics (134.6705, 384.6973) that showed the robustness of the model and the long-term associations among variables. These estimates led the authors to test long-term elasticities.

After determining the co-integration among variables, the long-run elasticities or parameters can be determined through ordinary least square (OLS), dynamic ordinary least square (DOLS) and fully modified ordinary least square (FMOLS) tests developed by Pedroni [51]. The estimated cointegrated vector through OLS is super convergent with the asymptotically biased distribution. These problems are similar for time series as well as for panel data and more salient even in the presence of heterogeneity [39]. Using the semiparametric corrections, FMOLS accounts for serial correlation and endogeneity in errors; on the other hand, DOLS uses the generalized least square procedure to correct the serial correlation in errors and leads and lags to correct the endogeneity in regressors [14]. So, the study has employed both estimators for robustness checks to estimate the long-term elasticities of variables, as both techniques correct the endogeneity and serial correlation problems. Table 5 presents the results of DOLS and FMOLS estimates. Results of FMOLS indicate that the institutional stability index has a negative and significant association with economic output; we can interpret this as a low institutional stability index indicating high stability (1 = most stable, 7 = least), that is why increased political stability will create increased economic output. So institutional stability plays a vital role in establishing the economy on a healthy footing. On the other hand, the DOLS results show a negative but insignificant association of institutional stability with economic output as found by Bulut and Muratoglu [26] in their DOLS estimation of democracy in a regional study of Turkey. Both capital and labor are significant contributors to economic output in both methods. The important parameters of economic output, renewable and non-renewable energy consumption contribute positively to economic development. So, both types of energy are essential for economic growth. This finding has a significant policy implication as it appeals to a blend of both types of energy and recommendations of a gradual transition to an eco-friendly energy system.

**Table 5**
DOLS and FMOLS estimates of long-term elasticities.

| Y = f(K L IS REC NREC) | | | $CO_2E$ = f(POPG PI IS REC NREC) | | |
|---|---|---|---|---|---|
| Variables | Coefficient | Prob | Variables | Coefficient | Prob |
| FMOLS estimates | | | | | |
| LNIS | −0.13431 | 0.0352 | LNIS | −0.31502 | 0.002 |
| LNK | 0.140893 | 0.0014 | LNPOPG | −0.12485 | 0.6634 |
| LNL | −0.5658 | 0.0504 | LNPI | 0.133255 | 0.0129 |
| LNNREC | 10.06462 | 0.0000 | LNREC | 0.575134 | 0.0011 |
| LNREC | 1.149324 | 0.0000 | LNNREC | 5.58897 | 0.0000 |
| DOLS estimates | | | | | |
| LNIS | −0.4177 | 0.0783 | LNIS | −0.12213 | 0.6033 |
| LNK | 0.372146 | 0.0067 | LNPOPG | −0.54772 | 0.1488 |
| LNL | −1.94931 | 0.0012 | LNPI | 0.309957 | 0.0065 |
| LNNREC | 13.19915 | 0.0000 | LNREC | 0.194662 | 0.2329 |
| LNREC | 1.24247 | 0.0000 | LNNREC | −2.03874 | 0.0352 |

Coming to the environment function, the FMOLS results indicate that the institutional stability index has a significant association with the environment, while it is insignificant in the DOLS estimation. Focusing on FMOLS estimation, we can infer that institutional stability and environmental degradation have a negative and significant association, as institutional stability will decrease environmental degradation by 0.31%. Population growth does not show a significant association while per capita income has a significant and positive impact on carbon emissions, which implies an increase in income spurs $CO_2$ emissions. We can presume therefore that the people of this region are not environmentally conscious yet, as they pollute their environment more as their level of income increases, so the government needs to establish a proper awareness campaign to educate the public about the importance of a clean environment.

Both renewable and non-renewable energy consumption have significant links with $CO_2$ emissions as predicted in FMOLS, but the results reveal that the beta coefficient of renewable energy consumption is much less than that of nonrenewable energy consumption, which implies that renewable energy consumption has a less damaging impact on the environment than nonrenewable energy consumption. We can further argue that renewable energy consumption needs technological involvement and proper planning of capital resources, but these countries are lacking in these fields, which is why renewable energy consumption is adding to the environmental pollution to some extent. Focusing on institutional quality, we can further argue that governments need to focus on technical aspects, clean production and consumption of energy, as most of the sources of renewable energy production are biogases and animal dungs that also have implications for the environment. So curtailing conventional sources and increasing clean production of renewable energy with greater emphasis on photovoltaic energy are recommended to grasp this opportunity.

The study proposed causality between independent variables and dependent variables for both of the equations. To analyze whether the causality is bidirectional, one way or if there is no causal association, the Granger causality approach is employed. The results presented in Table 6 indicate that there is no bidirectional causality between variables. As far as unidirectional causality is concerned, institutional stability Granger causes carbon emissions and renewable energy

**Table 6**
Granger causality test.

| Variables Links | F-statistics (p-value) | Decision | Variables Links | F-statistics (p-value) | Decision |
|---|---|---|---|---|---|
| LNIS toward LN$CO_2$E | 8.90070 (0.0002) | LNIS →LN $CO_2$E | LNIS towards LNGDP | 2.48580 (0.0859) | No causality |
| LNC$CO_2$E toward LNIS | 1.23828 (0.2922) | | LNGDP towards LNIS | 0.13878 (0.8705) | |
| LNPOPG towards LN $CO_2$E | 1.72636 (0.1806) | No causality | LNK towards LNGDP | 0.31723 (0.7285) | LNGDP→LNK |
| LN$CO_2$E towards LNPOPG | 0.15360 (0.8577) | | LNGDP towards LNK | 4.03479 (0.00192) | |
| LNPI towards LN $CO_2$E | 2.21398 (0.1120) | No causality | LNL towards LNGDP | 5.03387(0.0074) | LNL →LNGDP |
| LN$CO_2$E towards LNPI | 1.79590 (0.1687) | | LNGDP towards LNL | 0.12130 (0.8858) | |
| LNREC towards LN $CO_2$E | 0.96264 (0.3837) | No causality | LNNREC towards LNGDP | 0.66090 (0.5175) | No causality |
| LN$CO_2$E towards LNREC | 0.21365(0.8078) | | LNGDP towards LNNREC | 0.01937 (0.9808) | |
| LNNREC towards LN $CO_2$E | 2.88959 (0.0580) | No causality | LNREC towards LNGDP | 1.59010 (0.2065) | No causality |
| LN$CO_2$E towards LNNREC | 2.16708 (0.1173) | | LNGDP towards LNREC | 0.21113 (0.8099) | |
| LNPOPG towards LNIS | 0.83291 (0.4363) | No causality | LNK towards LNIS | 0.45486 (0.6352) | LNIS →LNK |
| LNIS towards LNPOPG | 0.58182 (0.5598) | | LNIS towards LNK | 3.46012 (0.0334) | |
| LNPI towards LNIS | 1.74885(0.1767) | No causality | LNL towards LNIS | 0.32191 (0.7252) | No causality |
| LNIS towards LNPI | 1.40277(0.2484) | | LNIS towards LNL | 0.33057 (0.7189) | |
| LNREC towards LNIS | 4.09167 (0.0182) | LNREC → LNIS | LNNREC towards LNIS | 0.31186 (0.7324) | No causality |
| LNIS towards LNREC | 0.00250 (0.9975) | | LNIS towards LNNREC | 0.02067 (0.9795) | |
| LNNREC towards LNIS | 0.31186 (0.7324) | No causality | LNREC towards LNIS | 4.09167 (0.0182) | LNREC→LNIS |
| LNIS towards LNNREC | 0.02067 (0.9795) | | LNIS towards LNREC | 0.00250 (0.9975) | |
| LNPI towards LNPOPG | 0.36700 (0.6933) | No causality | LNL towards LNK | 1.68114 (0.1888) | No causality |
| LNPOPG towards LNPI | 1.91489 (0.1501) | | LNK towards LNL | 0.98418 (0.3756) | |
| LNREC towards LNPOPG | 0.06775 (0.9345) | No causality | LNNREC towards LNK | 1.99022 (0.2394) | LNK→LNNREC |
| LNPOPG towards LNREC | 1.10422 (0.3335) | | LNK towards LNNREC | 8.11877 (0.0004) | |
| LNNREC towards LNPOPG | 2.13534 (0.1210) | No causality | LNREC towards LNK | 0.08201 (0.9213) | No causality |
| LNPOPG towards LNNREC | 0.21192 (0.8092) | | LNK towards LNREC | 0.09283 (0.9114) | |
| LNREC towards LNPI | 0.36036(0.6970) | No causality | LNNREC towards LNL | 0.22837 (0.796) | No causality |
| LNPI towards LNREC | 0.51532 (0.5981) | | LNL towards LNNREC | 0.65823 (0.5189) | |
| LNNREC towards LNPI | 0.10324 (0.9020) | No causality | LNREC towards LNL | 0.27677 (0.7585) | No causality |
| LNPI towards LNNREC | 0.43092 (0.6505 | | LNL towards LNREC | 0.34808 (0.7065) | |
| LNNREC towards LNREC | 0.03960 (0.9612) | No causality | LNREC towards LNNREC | 0.06929 (0.9331) | No causality |
| LNREC towards LNNREC | 0.06929 (0.9331) | | LNNREC towards LNREC | 0.03960 (0.9612) | |

consumption Granger causes institutional stability. For the second model, GDP and institutional stability Granger causes capital formation, labor force Granger causes GDP, while renewable energy Granger causes the capital formation and capital formation Granger causes nonrenewable energy. The study neither found any causality between energy consumption and economic growth nor with carbon emissions, hence the results support the neutrality hypothesis. The findings of the neutrality hypothesis are in line with previous findings where the authors have found no causal link [26], despite finding short and long-term associations among variables.

## 5. Conclusion

Energy has become a strategic commodity without which the functioning of the economy is threatened, especially in developing countries. Developing countries are facing the two-sided sword of energy challenges: On one hand, they have to overcome energy shortages and meet energy demand, while, on the other hand, environmental degradation poses a serious threat to sustainable development. That is why efforts are being made to spread the awareness of the utility and environmental compatibility of renewable energy. This study seeks to analyze the impact of renewable and nonrenewable energy consumption and institutional stability, along with other factors, on the environment and economic output or activity. The analysis is divided into two models; the first model pertains to the energy-institutional stability-economic growth nexus that incorporates the modified Cobb–Douglas production function. The second model pertains to the energy-institutional stability-environment quality nexus that incorporates the Diet and Rosa environmental function. D-8 countries were selected for analysis, as they mostly depend on conventional energy sources and suffer from low institutional quality. The data time period spans from 1990 to 2016 and panel data methodology is adopted for analysis. The authors applied different econometric techniques for the statistical analysis. The unit root test indicates that some of the variables are stationary at a level and some variables are stationary at first difference; that is why the ARDL bounds testing approach was incorporated to analyze the cointegration among variables. The results of both the equations indicate significant cointegration for the constituents of both functions. Further, the long-term elasticities are measured through FMOLS and DOLS estimation, where results indicate that both renewable and non-renewable energy has a strong association with economic development, as well as contributing to carbon emissions. However, the negative effect of renewable energy is much less than of nonrenewable energy. The variable of institutional stability positively impacts economic growth and environmental quality. The Granger causality results of the study support the neutrality hypothesis, as no causality is found in economic output and energy consumption.

Although the study has incorporated different indicators and measures, it is not beyond certain limitations. First, the study has employed important input factors for both of the functions but authors suggest incorporating some other resources as an input factor for environmental quality and economic growth, e.g. water resources, natural resource depletion. Second, the financial and economic integrations of economies and the mutual interplay of resources leads to common shocks and dependence of economies on each other that is termed “cross-sectional dependence”. The study has employed first-generation techniques of panel data analysis; ARDL, FMOLS and DOLS do not allow the consideration of cross-sectional dependence, the authors suggest incorporating the second-generation techniques of panel data analysis that addresses the cross-sectional dependence issue more accurately, e.g. dynamic common correlated method, common correlated effect mean group estimators.

### 5.1. Policy implications

Institutional stability is the basic parameter without which sustainable development cannot be imagined. The governments of these countries need to focus on cleaner energy production and the specific agenda of environmental protection to achieve sustainable development goals. Other suitable policy suggestions are:

- ➢ These countries are naturally blessed with different renewable energy sources due to their geographical location. But the statistics show that hydropower is the major source of renewable energy in these countries. So, the governments should not remain limited to this source and must invest in other sources to capitalize on other opportunities. Further, the governments should subsidize renewable energy consumption and should also maintain some other incentives, especially for rural electrification through renewable energy sources.
- ➢ Two of the D-8 member countries, Pakistan and Iran, have the ability to produce energy through nuclear technology. Therefore, these countries can enhance the production of renewable energy through nuclear technology for local use as well as for trade purposes. D-8 countries have various contracts along with efficient energy provision, so these countries can come up with effective nuclear as well as other energy trade agreements.
- ➢ Imposing a carbon tax on the excessive use of conventional energy sources and using that fund for proper procurement of renewable energy will eventually enable renewable energy to compete with conventional sources. So the governments are recommended to ensure the proper implementation of policies to abate the environmental consequences of conventional energy sources.
- ➢ Last but not least, a public awareness campaign, to spread the knowledge about the usability of renewable energy and anthropogenic implications of conventional energy, should be scheduled through proper training and programs. The governments of these countries are encouraged to arrange such a media campaign to urge and educate the public to participate in making the world a better place to live in for themselves and future generations.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## CRediT authorship contribution statement

**Mahjabeen:** Conceptualization, Writing - original draft, Data curation. **Syed Z.A. Shah:** Conceptualization, Supervision, Validation. **Sumayya Chughtai:** Methodology, Software, Writing - review & editing. **Biagio Simonetti:** Formal analysis.

## References


[1] S. Sen, S. Ganguly, Opportunities, barriers and issues with renewable energy development – a discussion, Renew. Sustain. Energy Rev. 69 (2017) 1170–1181, https://doi.org/10.1016/j.rser.2016.09.137.

[2] T.W. Brown, T. Bischof-Niemz, K. Blok, C. Breyer, H. Lund, B.V. Mathiesen, Response to 'Burden of proof: a comprehensive review of the feasibility of 100% renewable-electricity systems,', Renew. Sustain. Energy Rev. 92 (2018) 834–847, https://doi.org/10.1016/j.rser.2018.04.113.

[3] M. Bhattacharya, S. Awaworyi Churchill, S.R. Paramati, The dynamic impact of renewable energy and institutions on economic output and CO 2 emissions across regions, Renew. Energy 111 (2017) 157–167, https://doi.org/10.1016/j.renene.2017.03.102.

[4] A.A.F. Husain, W.Z.W. Hasan, S. Shafie, M.N. Hamidon, S.S. Pandey, A review of transparent solar photovoltaic technologies, Renew. Sustain. Energy Rev. 94 (2018) 779–791, https://doi.org/10.1016/j.rser.2018.06.031.

[5] M. Ahmad, G. Jabeen, M. Irfan, M. Claire, M. Naseer, A. Maria, Modeling causal interactions between energy investment , pollutant emissions , and economic Growth : China study, Biophys. Econ. Sustain. 7 (2020) 1–12, https://doi.org/10.1007/s41247-019-0066-7.

[6] B.M. Eren, N. Taspinar, K.K. Gokmenoglu, The impact of financial development and economic growth on renewable energy consumption: empirical analysis of India, Sci. Total Environ. 663 (2019) 189–197, https://doi.org/10.1016/j.scitotenv.2019.01.323.

[7] M. Kahia, M.S. Ben Aïssa, C. Lanouar, Renewable and non-renewable energy use - economic growth nexus: the case of MENA Net Oil Importing Countries, Renew. Sustain. Energy Rev. 71 (2017) 127–140, https://doi.org/10.1016/j.rser.2017.01.010.

[8] W.U.K. Tareen, Z. Anjum, N. Yasin, L. Siddiqui, I. Farhat, S.A. Malik, S. Mekhilef, M. Seyedmahmoudian, B. Horan, M. Darwish, M. Aamir, L.W. Chek, The prospective non-conventional alternate and renewable energy sources in Pakistan - a focus on biomass energy for power generation, transportation, and industrial fuel, Energies 11 (2018), https://doi.org/10.3390/en11092431.

[9] D. Gielen, F. Boshell, D. Saygin, M.D. Bazilian, N. Wagner, R. Gorini, The role of renewable energy in the global energy transformation, Energy Strateg. Rev. 24 (2019) 38–50, https://doi.org/10.1016/j.esr.2019.01.006.

[10] M. Kamran, Current status and future success of renewable energy in Pakistan, Renew. Sustain. Energy Rev. 82 (2018) 609–617, https://doi.org/10.1016/j.rser.2017.09.049.

[11] K. Dong, G. Hochman, Y. Zhang, R. Sun, H. Li, H. Liao, CO 2 emissions, economic and population growth, and renewable energy: empirical evidence across regions, Energy Econ. 75 (2018) 180–192, https://doi.org/10.1016/j.eneco.2018.08.017.

[12] S.A. Sarkodie, S. Adams, Renewable energy, nuclear energy, and environmental pollution: accounting for political institutional quality in South Africa, Sci. Total Environ. 643 (2018) 1590–1601, https://doi.org/10.1016/j.scitotenv.2018.06.320.

[13] S.R. Paramati, A. Sinha, E. Dogan, The significance of renewable energy use for economic output and environmental protection: evidence from the Next 11 developing economies, Environ. Sci. Pollut. Res. 24 (2017) 13546–13560, https://doi.org/10.1007/s11356-017-8985-6.

[14] S. Adams, E.K.M. Klobodu, A. Apio, Renewable and non-renewable energy, regime type and economic growth, Renew. Energy 125 (2018) 755–767, https://doi.org/10.1016/j.renene.2018.02.135.

[15] N. Apergis, J.E. Payne, Renewable energy consumption and growth in Eurasia, Energy Econ. 32 (2010) 1392–1397, https://doi.org/10.1016/j.eneco.2010.06.001.

[16] S. Farhani, M. Shahbaz, What role of renewable and non-renewable electricity consumption and output is needed to initially mitigate CO2 emissions in MENA region? Renew. Sustain. Energy Rev. 40 (2014) 80–90, https://doi.org/10.1016/j.rser.2014.07.170.

[17] M. Mert, G. Bölük, Do foreign direct investment and renewable energy consumption affect the CO2emissions? New evidence from a panel ARDL approach to Kyoto Annex countries, Environ. Sci. Pollut. Res. 23 (2016) 21669–21681, https://doi.org/10.1007/s11356-016-7413-7.

[18] F. Bilgili, E. Koçak, Ü. Bulut, The dynamic impact of renewable energy consumption on CO 2 emissions: a revisited Environmental Kuznets Curve approach, Renew. Sustain. Energy Rev. 54 (2016) 838–845, https://doi.org/10.1016/j.rser.2015.10.080.

[19] G. Heal, Reflections-the economics of renewable energy in the United States, Rev. Environ. Econ. Pol. 4 (2009) 139–154, https://doi.org/10.1093/reep/rep018.

[20] F.M. Mirza, A. Kanwal, Energy consumption, carbon emissions and economic growth in Pakistan: dynamic causality analysis, Renew. Sustain. Energy Rev. 72 (2017) 1233–1240, https://doi.org/10.1016/j.rser.2016.10.081.

[21] U.K. Mirza, N. Ahmad, K. Harijan, T. Majeed, Identifying and addressing barriers to renewable energy development in Pakistan, Renew. Sustain. Energy Rev. 13 (2009) 927–931, https://doi.org/10.1016/j.rser.2007.11.006.

[22] M.K. Shahzad, A. Zahid, T. Rashid, M.A. Rehan, M. Ali, M. Ahmad, Techno-economic feasibility analysis of a solar-biomass off grid system for the electrification of remote rural areas in Pakistan using HOMER software, Renew. Energy 106 (2017) 264–273, https://doi.org/10.1016/j.renene.2017.01.033.

[23] R. Bellakhal, S. Ben Kheder, H. Haffoudhi, Governance and renewable energy investment in MENA countries:How does trade matter? Energy Econ. 84 (2019) 104541, https://doi.org/10.1016/j.eneco.2019.104541.

[24] S. Adams, E.K.M. Klobodu, E.E.O. Opoku, Energy consumption, political regime and economic growth in sub-Saharan Africa, Energy Pol. 96 (2016) 36–44, https://doi.org/10.1016/j.enpol.2016.05.029.

[25] S. Adams, P.K. Adom, E.K.M. Klobodu, Urbanization, regime type and durability, and environmental degradation in Ghana, Environ. Sci. Pollut. Res. 23 (2016) 23825–23839, https://doi.org/10.1007/s11356-016-7513-4.

[26] U. Bulut, G. Muratoglu, Renewable energy in Turkey: great potential, low but increasing utilization, and an empirical analysis on renewable energy-growth nexus, Energy Pol. 123 (2018) 240–250, https://doi.org/10.1016/j.enpol.2018.08.057.

[27] O. Ocal, A. Aslan, Renewable energy consumption-economic growth nexus in Turkey, Renew. Sustain. Energy Rev. 28 (2013) 494–499, https://doi.org/10.1016/j.rser.2013.08.036.

[28] M. Shahbaz, N. Loganathan, M. Zeshan, K. Zaman, Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan, Renew. Sustain. Energy Rev. 44 (2015) 576–585, https://doi.org/10.1016/j.rser.2015.01.017.

[29] E.U.A.R. Osa, Effects of population and affluence on CO 2 emissions, Ecology 94 (1997) 175–179.

[30] I.M.A. Bengochea-morancho, R. Morales-lage, The Impact of Population on CO 2 Emissions : Evidence from European Countries, Foxit Reader, 2007, pp. 497–512, https://doi.org/10.1007/s10640-007-9096-5.

[31] S. Adams, E.K.M. Klobodu, Urbanization, democracy, bureaucratic quality, and environmental degradation, J. Pol. Model. 39 (2017) 1035–1051, https://doi.org/10.1016/j.jpolmod.2017.04.006.

[32] E. Productivity, D -8 Economic Outlook 2016/2017, 2017.

[33] A. Kraft, John kraft, on the relationship between energy and GNP author ( s ): John Kraft and Arthur Kraft stable, J. Energy Dev. 3 (1978) 401–403. On the Relationship Between Energy and GNP, http://www.jstor.org/stable/24806805.

[34] T. Chien, J.L. Hu, Renewable energy and macroeconomic efficiency of OECD and non-OECD economies, Energy Pol. 35 (2007) 3606–3615, https://doi.org/10.1016/j.enpol.2006.12.033.

[35] S.S. Amjid, M.Q. Bilal, M.S. Nazir, A. Hussain, Biogas, renewable energy resource for Pakistan, Renew. Sustain. Energy Rev. 15 (2011) 2833–2837, https://doi.org/10.1016/j.rser.2011.02.041.

[36] X.C. Yuan, Y.J. Lyu, B. Wang, Q.H. Liu, Q. Wu, China's energy transition strategy at the city level: the role of renewable energy, J. Clean. Prod. 205 (2018) 980–986, https://doi.org/10.1016/j.jclepro.2018.09.162.

[37] P. Sadorsky, Renewable energy consumption and income in emerging economies, Energy Pol. 37 (2009) 4021–4028, https://doi.org/10.1016/j.enpol.2009.05.003.

[38] N. Apergis, J.E. Payne, The causal dynamics between renewable energy, real GDP, emissions and oil prices: evidence from OECD countries, Appl. Econ. 46 (2014) 4519–4525, https://doi.org/10.1080/00036846.2014.964834.

[39] S. Farhani, Renewable energy consumption, economic growth and CO2 emissions: evidence from selected MENA countries, Energy Econ. Lett. 1 (2013) 24–41, https://doi.org/10.1109/GLOCOM.2010.5683968.

[40] M. Sebri, O. Ben-Salha, On the causal dynamics between economic growth, renewable energy consumption, CO2emissions and trade openness: fresh evidence from BRICS countries, Renew. Sustain. Energy Rev. 39 (2014) 14–23, https://doi.org/10.1016/j.rser.2014.07.033.

[41] Danish, B. Zhang, B. Wang, Z. Wang, Role of renewable energy and non-renewable energy consumption on EKC: evidence from Pakistan, J. Clean. Prod. 156 (2017) 855–864, https://doi.org/10.1016/j.jclepro.2017.03.203.

[42] R. Zeb, L. Salar, U. Awan, K. Zaman, M. Shahbaz, Causal links between renewable energy, environmental degradation and economic growth in selected SAARC countries: progress towards green economy, Renew. Energy 71 (2014) 123–132, https://doi.org/10.1016/j.renene.2014.05.012.

[43] F.V. Bekun, A.A. Alola, S.A. Sarkodie, Toward a sustainable environment: nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries, Sci. Total Environ. 657 (2019) 1023–1029, https://doi.org/10.1016/j.scitotenv.2018.12.104.

[44] K. Dong, R. Sun, G. Hochman, Do natural gas and renewable energy consumption lead to less CO2 emission? Empirical evidence from a panel of BRICS countries, Energy 141 (2017) 1466–1478, https://doi.org/10.1016/j.energy.2017.11.092.

[45] K. Dong, X. Dong, C. Dong, Determinants of the global and regional CO 2 emissions: what causes what and where? Appl. Econ. (2019) 1–14, https://doi.org/10.1080/00036846.2019.1606410, 00.

[46] S. Saint Akadiri, F.V. Bekun, S.A. Sarkodie, Contemporaneous interaction between energy consumption, economic growth and environmental sustainability in South Africa: what drives what? Sci. Total Environ. 686 (2019) 468–475, https://doi.org/10.1016/j.scitotenv.2019.05.421.

[47] S.A. Sarkodie, V. Strezov, Assessment of contribution of Australia's energy production to CO2 emissions and environmental degradation using statistical dynamic approach, Sci. Total Environ. 639 (2018) 888–899, https://doi.org/10.1016/j.scitotenv.2018.05.204.

[48] U. Al-Mulali, I. Ozturk, The effect of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation in the MENA (Middle East and North African) region, Energy 84 (2015) 382–389, https://doi.org/10.1016/j.energy.2015.03.004.

[49] J. Baek, A new look at the FDI-income-energy-environment nexus: dynamic panel data analysis of ASEAN, Energy Pol. 91 (2016) 22–27, https://doi.org/10.1016/j.enpol.2015.12.045.

[50] M.H. Pesaran, Y. Shin, R.J. Smith, Bounds testing approaches to the analysis of level relationships, J. Appl. Econom. 16 (2001) 289–326, https://doi.org/10.1002/jae.616.

[51] P. Pedroni, Fully modified Ols for heterogeneous cointegrated panels. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.294.1320&rep=rep1&type=pdf, 2000.