Technological Forecasting & Social Change 181 (2022) 121756

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

The roles of technology and Kyoto Protocol in energy transition towards COP26 targets: Evidence from the novel GMM-PVAR approach for G-7 countries

Eyup Dogan[a,f,*], Muhammad Zubair Chishti[b,c], Nooshin Karimi Alavijeh[d], Panayiotis Tzeremes[e]

[a] *College of Business Administration, University of Sharjah, United Arab Emirates*
[b] *School of Business, Zhengzhou University, Henan, China*
[c] *School of Economics, Quaid I Azam University, Islamabad, Pakistan*
[d] *Department of Economics, Ferdowsi University of Mashhad, Mashhad, Iran*
[e] *Department of Accounting and Finance, University of Thessaly, Greece*
[f] *Department of Economics, Abdullah Gul University, Turkey*

ARTICLE INFO

Keywords:
Energy transition
Environmental policy
Renewable technology
Sustainable development

ABSTRACT

The investigation of the determinants of energy transition has become very attractive and popular due to the Sustainable Development Goals and COP26 targets. However, one shortcoming of the existing studies is the inability to understand the effects of technology and environmental policy to energy transition while the other criticism is the use of conventional techniques that do not handle the endogeneity issue. Thus, this study investigates the impacts of technology and Kyoto Protocol in addition to several control variables to energy transition by applying the novel econometric method of Sigmund and Ferstl (2021) on the annual data from 2000 to 2019 for G-7 countries. The empirical results confirm the positive and significant link between technology and energy transition, such that, a 1% rise in technology enhances the energy transition by 0.32%. Similarly, Kyoto Protocol has a significantly positive impact on energy transition. An explanation is that the Protocol is based on principles and policies that emphasize the advanced and industrialized economies to enhance the environmental quality by promoting the renewable energy resources and reducing the greenhouse gases. Furthermore, the G-7 authorities should start to provide subsidies to clean energy and technology-related investors and levy multiple disincentives (i.e., higher tax rates) on the industries deploying the conventional and polluting methods for energy production. Further policy implications are discussed in the study.

1. Introduction

The Glasgow Climate Pact (COP26) held in November 2021 is a key collective effort to speed up energy transition to achieve net-zero emissions by 2050. This is by all means a big step in line with Sustainable Development Goals (SDGs) after the initiation of Kyoto Protocol and Paris Agreement that aim to control for climate change and global warming. Even though the intergovernmental parties and policymakers aim to limit the rise in global temperature to 1.5 °C, the levels of pollution are still remarkably high. In detail, carbon dioxide (CO_2) emissions amount was 278 ppm before the industrial revolution but it reached 316, 365, 400 and 412 ppm in 1959, 1998, 2015 and 2020, respectively (Salehnia et al., 2020; NOAA, 2021). Tollefson (2020) argues that the global temperature is predicted to rise by 5–6 °C by the end of this century if the CO_2 continues to rise at this pace.

In recent decades, climate change has been considered as a global environmental problem and it is a serious threat to sustainable development (Afrifa et al., 2020; Jiang et al., 2021). The concerns about climate change and global warming as well as restrictions on the use of fossil fuels incentive energy transition to the sustainable and renewable energy sector (Gallo et al., 2016; Gozgor, 2018). So that renewable energy development has become a key component in the transformation towards a low-carbon economy (Przychodzen and Przychodzen, 2020). Global demand for renewable energy is increasing day by day. Tolliver

* Corresponding author at: College of Business Administration, University of Sharjah, United Arab Emirates
E-mail addresses: eyup.dogan@agu.edu.tr, edogan@sharjah.ac.ae (E. Dogan), mzchishti@eco.qau.edu.pk (M.Z. Chishti), n.karimialavijeh@mail.um.ac.ir (N. Karimi Alavijeh), tzeremes@econ.uth.gr (P. Tzeremes).

https://doi.org/10.1016/j.techfore.2022.121756
Received 30 January 2022; Received in revised form 15 May 2022; Accepted 16 May 2022
Available online 26 May 2022
0040-1625/

et al. (2020) mention that the share of renewable energy in total energy is projected to increase by 60% through 2040 to accomplish the three energy-related SDGs. Moreover, the International Renewable Energy Agency has stated that two-thirds of the global total energy supply will come from renewable energy sources by 2050 (IRENA, 2020). Most renewables sources produce no or minimal emissions, as a result, they are beneficial to the environment. Thus, promoting the development of renewables is important to achieving sustainable economic growth (Le et al., 2020). Given the role of renewable energy in the sustainable energy discussion, identifying the drivers of energy deployment and transition is important for energy policy. Additionally, global consensus has emerged on spreading clean energy production and reducing fossil energy demand, such as the Kyoto Protocol, adopted in 1998 and entered into force in 2005, marked a turning point in promoting CO_2 decrease and has become a catalyst in promoting renewable energy consumption worldwide (UNFCCC, 2010; Rahman et al., 2010). It is expected, the countries that have signed the protocol have strong obligation to renewable energy transition (Popp et al., 2011). The empirical evidence has displayed positive impacts of the implementation of the Kyoto Protocol on renewable energy development (Brunnschweiler, 2010; Aguirre and Ibikunle, 2014).

An environmental variable is an important factor for energy transition (Bourcet, 2020). While several researchers have concluded that high levels of CO_2 emissions encourage the development and use of renewable energy (Sadorsky, 2009; Omri and Nguyen, 2014; Lu, 2017), a group of studies have shown that environmental pressures do not support the renewable energy transition. For instance, Lucas et al. (2016) attributed the negative impact of CO_2 emissions on the development of renewable energy to the dependency on fossil fuels and the power of lobbies. Baye et al. (2021) believe that the negative effect of CO_2 emissions on renewables may be owing to the complementarity between renewable energy production and CO_2 emissions in smaller quantities. In fact, CO_2 emissions do not play a strong role in exhorting renewables development (Marques et al., 2010; Marques and Fuinhas, 2011; Papież et al., 2018; Bayale et al., 2021). Likewise, achieving economic growth (i.e., GDP) is a fundamental goal for attaining sustainable development. Thus, economic growth is a stimulus that encourages and directs countries towards renewable energy. In other words, higher GDP can support regulatory costs to upgrade renewables, because renewable technologies usually cost more than fossil fuels (Bamati and Raoofi, 2020). Thus, promoting economic development leads to the development of renewable energy. Ibrahiem and Hanafy (2021) supported the role of economic growth in development renewable energy sources in North African countries. Also, Polcyn et al. (2022) noted that GDP is the main driving for the development of renewable energy in selected European countries. In addition, it is believed that high-income countries are often moving faster towards energy transition than low-income countries, because they can easily pay the costs of development renewable technologies (Chang et al., 2009; Sadorsky, 2009; Bersalli et al., 2020). Almost all researchers have demonstrated that there is a positive relationship between income and renewable energy development (e.g., Salim and Rafiq, 2012; Koçak and Şarkgüneşi, 2017; Gozgor et al., 2018; Eren et al., 2019).

The use of new technologies is undoubtedly one of the key tools in the clean energy transition from fossil fuels to low-carbon energy sources. Hence, investment in clean energy technologies, which are more efficient than current technologies, has expanded significantly (Lee and Yang, 2019). The promotion of renewable energy technologies will decrease development and maintenance costs and improve the usability and efficiency of energy conversion to promote renewable energy development (Dincer, 2001). From another perspective, Miremadi et al. (2019) concluded that developments in renewable energy are very essential to control climate change. Factors influencing technology development include renewable energy capabilities and research and development (Xu et al., 2019). In this line, Wang et al. (2020) highlighted that a country's research and development investment plays an important role in promoting renewable energy. There are different technological options for increasing shares of renewable energy sources. One of those is storage technologies that contributes to the more efficient use of renewable energy capacity and plays a rising role in the renewables transition (Schill, 2020). Fisher-Vanden et al. (2004) and Jiahua et al. (2010) showed that technological progress promotes renewable energy development, and increasing the renewable energy capacity is the stimulus for renewable energy transition and development (Essletzbichler, 2012).

This study attempts to address the two limitations of the existing literature. First, previous studies on technology development have focused on research and development investment and storage technologies for the energy transition. However, the present study tries to expand the relevant literature by considering the energy transfer capacity. Second, previous literature has not simultaneously explored the role of the Kyoto Protocol alongside the technology development factor on renewable energy deployment.

In light of the above-mentioned explanations and arguments, the objective of this study is to evaluate the impact of technology and Kyoto protocol on energy transition by applying the novel econometric method-Panel Vector Autoregressive model in Generalized Method of Moments (GMM-PVAR)-of Sigmund and Ferstl (2021) on the data for the period 2000–2019 for G-7 countries. This issue is important for two reasons: (1) the essential role of renewable energy in achieving Sustainable Development Goals and COP26 targets; and (2) the key role of technology and environment-related policy in the energy transition. Thus, this study applies the GMM-PVAR in the energy transition/renewable energy deployment literature. In view of likely endogeneity issue in the estimated models, this attempt is very supportive and original to obtain more reliable and robust outcomes than those of the existing studies that mostly rely on conventional econometric techniques. Also, this study considers the impact of technology and Kyoto Protocol as an environmental policy on energy transition for the G-7 group as the seven largest industrial countries in the world.

Among all the economies, the G-7 members are seven of the most advanced and industrialized countries (Canada, France, Germany, Italy, Japan, the UK, and the USA). These countries accounted for approximately 56% of the world GDP in 2019 (World Bank, 2020). G-7 countries emitted 7835 million tons of carbon dioxide in 2020 that was 22.50% of world emissions. According to the International Energy Agency (2021) report, the G-7 allocated 36% of global power generation capacity and 30% of global energy demand. In 2020, the primary sources of electricity were natural gas and renewables each creating about 30% of the total electricity. Also based on this report, renewables energies on track to reach 48% of electricity supply, and for reaching to net zero by 2050, renewables have to supply 60% of electricity supply by 2030. Hence, in order to reduce global emissions and prevent climate change, it is necessary to examine the factors affecting the transition of renewable energy in the G7 countries.

The paper is structured as follows. Section 2 contains literature review. Section 3 provides the data and the methodology approach. The results and discussion are presented in Section 4, while Section 5 derives conclusions and policy recommendations.

2. Literature review

Given the increase in environmental pollution and the need towards renewable energy deployment, this issue has received considerable attention in recent decades. Empirical evidence has shown that several factors can affect the development of renewable energy and energy transition. In general, previous studies can be listed on three groups.

2.1. Economic factors

The first group is studies that have examined the impact of economic factors on energy transition and the development of renewable energy.

Economic factors focus on economic growth, per capita income, trade openness, access to financial capital, price of fossil fuels, greenhouse gas emissions and utilization of the labor force. Several studies have demonstrated this statement. For example, Brunnschweiler (2010) investigated the impact of finance sector on development renewable energy in developing and transition economies by random-effects GLS and dynamic GMM. He has shown that financial sector development in particular commercial banking has the significant impact on the use of renewable energy resources in 119 non-OECD countries during 1980–2006. Using a random effect model, Menegaki (2011) revealed that there are short-run relationships between renewable energy and greenhouse gas emissions for 27 European countries. Pfeiffer and Mulder (2013) have indicated the diffusion of non-hydro renewable energy technologies for electricity generation. To this end, they surveyed 108 developing countries for the period 1980 to 2010 by two-stage estimation methods (the two-part model and the two-step selection model). They concluded that higher per capita income accelerates non-hydro renewable energy diffusion and transition. They also showed that a various energy mix increases the probability of non-hydro renewable energy development. Omri and Nguyen (2014) investigated the determinants of renewable energy consumption in 64 countries (high, middle, and low-income) during 1990–2011 by using a dynamic GMM panel model. Their results demonstrated that trade openness and increases in CO_2 emissions rise renewable energy consumption. Also, in the middle-income countries and global panels, the impact of Oil price increases on renewable energy consumption is negative.

A study on oil producing African countries by Ackah and Kizys (2015) on the period from 1985 to 2010 aimed to investigates the drivers of renewable energy demand. Three panel models were used to analyze the data in this study (a random effect model, a fixed effects model and a dynamic panel data model). The finding of this study proposes that real income per capita and energy prices are the main stimulus of renewable energy. Using panel method Menegaki and Ozturk (2016) showed that there is a bidirectional relationship between fossil fuel energy consumption and renewable energy consumption for MENA countries in period 1997–2009. Igliński et al. (2016) analyzed production of renewable energy in the Łódzkie Voivodeship (Poland). They have resulted that a high unemployment rate let to renewable energy production. Whit applying panel cointegration methods, Lin and Omoju (2017) showed financial development and economic development have a positive impact on the amount of non-hydro renewable electricity generation in 46 developed and developing countries during 1980–2011. A research on European countries was conducted by Jacqmin (2018). He estimated the impact Economic Freedom Index on the production of energy from renewable sources using a dynamic panel approach from 2003 to 2012. According to the mentioned model, the results showed that freedom to trade and long-term price stability enhance the reliance on renewable energies. By panel ARDL method, da Silva et al. (2018) concluded that CO_2 emissions negatively affected renewable energy in sub-Saharan African countries for the period 1990–2014.

With estimating correlation and decomposition methods, Khuong et al. (2019) have explored the drivers of renewable energy development in Southeast Asia countries from 1995 to 2013. The results designated that economic growth and urbanization create a great motivation for renewable energy development. Using the random-effects and the panel FMOLS estimations Gozgor et al. (2020) showed the per capita income, the real price of oil, the per capita carbon dioxide emissions had a positive impact on renewable energy that in 30 OECD countries from 1970 to 2015. Using NARDL estimation, Urom et al. (2021) concluded that renewable energy consumption is due to globalization, positive shocks on income and capital in G7 Countries. Based on Bayesian Model Averaging, Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) approaches, Bayale et al. (2021) stated that real GDP per capita, and unemployment increase renewable energy development, but CO_2 emissions interdict renewable energy generation in WAEMU countries. Karacan et al. (2021) investigated the relationship between economic growth, oil price and renewable consumption in Russia by utilizing the Vector Error Correction Models and the Canonical Cointegrating Regression method from 1990 to 2015. The result indicated the negative impact oil price on consumption of renewable energy, while influence of GDP per capita was positive and significant on renewable consumption. Based on the two techniques of the pooled ordinary least squares with robust SEs and the augmented mean group estimator, Dogan et al. (2021) found an increase in GDP per capita leads to an increase in renewable energy in 24 developed and 48 developing for the period from 1980 to 2016. Mukhtarov et al. (2022a) used a General to Specific modeling method to explore the influence of oil price on the renewable energy consumption (REC) for Iran for the period of 1980–2019. By VECM and ARDL techniques, Mukhtarov et al. (2022b) evaluated the impact of economic growth, and energy prices on renewable energy consumption in Turkey from 1980 to 2019. The results showed a positive and significant effect of economic growth on renewable energy. The estimation findings discovered that the price of oil and emissions have a negative effect on REC. Samour et al. (2022) found economic growth can increase renewable energy consumption in the UAE from 1989 to 2019, by the technique of bootstrap autoregressive distributed lag. Other similar studies in this group are Corsatea et al. (2014), Cadoret and Padovano (2016).

2.2. Policy factors

The second group is studies that considered the political drivers of renewable energy development. Policy drivers include participation in international commitments to reduce greenhouse gas emissions (e.g., Kyoto Protocol, Paris Agreement and etc.) and the implementation of competitive policies (e.g., privatization). For an instant, Sequeira and Santos (2018) reviewed relation between renewable energy and politics. Their results demonstrated democratic countries are more inclined to invest in renewable energy. Liu et al. (2019) appraised the impact of renewable energy policy in 29 countries from 2000 to 2015 by the panel data model. The empirical findings indicated that the execution of the Kyoto Protocol has had a positive impact on the development of renewable energy. By applying a panel data on the transition economies in Central and Eastern Europe and the Caucasus and Central Asia Przychodzen and Przychodzen (2020) have indicated that the implementation of the Kyoto Protocol led to the increase in the renewable energy development from 1990 to 2014. But the implementation of the competition policy has limited utilization of renewable energy. Uzar (2020) analyzed the institutional quality on renewable energy consumption in 38 countries during 1990–2015. The findings indicated that institutional quality has the impact of positive on renewable consumption. By using panel threshold model in 97 countries Chen et al. (2021) found that democratic institutions have a considerable role in renewable energy use from 1995 to 2015. Using panel quantile method, Belaïd et al. (2021) investigated drivers of renewable energy production in the MENA countries. They showed that political stability, and governance effectiveness are important drivers for renewable energy deployment. More related researches are those of Marques and Fuinhas (2012).

2.3. Technical factors

The third group investigated the technical factors affecting the development and production of renewable energy. This factor contains renewable energy capacity, and research and development capabilities. For example, Zhao et al. (2019) examined the factors influencing the development of renewable energy projects in China. They concluded that research and development is an important factor in the development of renewable energy. With estimating panel data models, Wang et al. (2020) have displayed that research and development has the major contributor in the development of renewable energy in middle-income countries of G20 from 1990 to 2017. By applying ARDL model in 25 OECD countries Alam and Murad (2020) showed the significant influence of technological progress on renewable energy use over the long-term. By Delphi survey, Chen et al. (2020) indicated that technology development is a vital driver for the deployment of renewable energy to 2030 in China. Using GLS method Bamati and Raoofi (2020) analyzed the drivers of renewable energy production by factors of technological, economic, and environmental. They found that high technology export drives renewable energy use in developed countries, but high technology export isn't the driver of renewable energy in developing countries. There are also similar studies with identified findings, such as Gan and Smith (2011).

Since several factors affect the energy transition, researchers have applied various statistical methods to model the three groups as mentioned above. Nevertheless, this study investigates the impact of technology and Kyoto Protocol along with economic factors on energy transitions in G-7 countries through the novel GMM-PVAR method and contributes to the development of existing literature.

3. Model, data and methodology

We aim to investigate the effect of technology and policy on energy transition for G-7 countries. In view of existing studies discussed in the literature review section and inspired by the review study Bourcet (2020) and the recent study Dogan et al. (2021), this study focuses on the following model:

$$ENTR_{it} = f(GDP_{it}, CO_{2it}, FPR_{it}, KYOTO_{it}, RECAP_{it}) \quad (1)$$

As energy transition (ENTR), we use the share of primary energy from renewable energy sources while we utilize Gross Domestic Product (GDP) calculated in billions of 2017 USD, fossil fuel prices (FPR) as economic variables and carbon dioxide emissions (CO_2) calculated in billion tons as an environmental variable, the installed renewable power capacity as technology variable (RECAP), and the Kyoto protocol as policy variable-KYOTO is a binary variable where it takes the value of 1 if depicts ratification of the protocol and 0 if depicts no ratification of the protocol. The sample period is 2000–2019 given it is the maximum available span of data for the variables under consideration for G-7 countries: Canada, France, Germany, Italy, Japan, United Kingdom (UK), and United States of America (USA). The definitions and sources of the variables employed in this paper are shown in Table 1.

Figs. 1 and 2 display energy transition, and renewable energy capacity for the G-7 countries over the period 2000–2019. The finding of Fig. 1 displays the share of primary energy from renewable sources. Canada has the highest energy transition of 28.77% in 2009, while United Kingdom has the lowest energy transition of 0.98% in 2001. According to Fig. 1, the share of primary energy from renewable sources in the G-7 countries increased during the period 2000–2019. The outputs of Fig. 2 show renewable energy capacity in G-7 countries. United States of America and United Kingdom have the highest and lowest installed renewable energy power capacity during the period under review, respectively. As can be seen, the installed renewable energy power capacity of all countries has increased in the period 2000–2019.

Table 1
Definition of variables.

Variables	Definitions	Sources
ENTR	Share of primary energy from renewable sources (%)	Our World in Data - Ritchie and Roser (2020a)
GDP	Gross domestic product (US$ 2017)	Penn World Table 10.0
CO_2	Carbon dioxide emissions (billion tonnes)	Our World in Data - Ritchie and Roser (2020b)
FPR	Fossil fuel prices (US $)	BP Statistics (2021)
RECAP	Installed renewable energy power capacity (MW)	IRENA (2020)
KYOTO	Ratification of the Kyoto Protocol	UNFCCC-Kyoto Protocol

3.1. Methodology

To perform the econometric analysis, the five-step econometric approach is deployed. Firstly, Pesaran's (2004) test is utilized in order to affirm the cross-sectional dependence (CD) across the selected series. Secondly, we use CAFD and CIPS unit root tests for checking the stationary (Pesaran, 2007). Thirdly, two advanced tests of cointegration (Kao, 1999; Westerlund, 2007) are applied to analyze the long-run association among the modeled constructs. Fourthly, the novel GMM-PVAR technique is deployed for the long-run parameters estimation. Lastly, some diagnostics tests are performed which confirm the results' robustness.

3.1.1. GMM-Panel VAR technique

Holtz-Eakin et al. (1988) constructed the panel vector autoregressive model (PVAR). Recently, Sigmund and Ferstl (2021) extend this PVAR fashion encompassing multiple w lags of a endogenous covariates, l weakly exogenous (predetermined) and d strictly exogenous covariates. Hence, a new stationary PVAR with fixed effects with the mentioned parameters was introduced:

$$g_{i,t} = q_i + \sum_{n=1}^{w} K_n g_{i,t-n} + V\theta_{i,t} + Fz_{i,t} + p_{i,t} \quad (2)$$

where $g_{i,\ t-1}$ are the endogenous variables at time t, $\theta_{i,\ t}$ denotes the weakly exogenous (predetermined) variables while $z_{i,\ t}$ shows the strictly exogenous covariates. Additionally, fixed effects can be eliminated either with first difference or the forward orthogonal transformation procedure. Besides, implementing Generalized Method of Moments (GMM) model we can adopt more robust findings utilizing the coefficients as instrumentals variables. Moreover, Sigmund and Ferstl (2021) modified and extended the estimator of Binder et al. (2005) by increasing the lags of the endogenous, weakly and strictly exogenous covariates. Therefore, using the first difference or the forward orthogonal transformation the model of Eq. (2) was constructed as follows:

$$\Delta g_{i,t} = \sum_{n=1}^{w} K_n \Delta g_{i,t-n} + V\Delta\theta_{i,t} + F\Delta z_{i,t} + \Delta p_{i,t} \quad (3)$$

in Eq. (3) Δ denotes the first difference or the forward orthogonal transformation. The lagged endogenous variable, $g_{i,\ t}$, for our study are RE, GDP and CO_2, $\theta_{i,\ t}$ stands for the weakly exogenous variables (predetermined), for our study are the variables FFRP and RECAP while $z_{i,\ t}$ demonstrates the strictly exogenous variables, which is KYOTO variable. The stability of PVAR framework is examined following the modulus of each eigenvalue of the calculated model, if all the eigenvalues lie inside the unit circle (values are strictly less than one), then PVAR satisfies stability condition. Lastly, lag selection criteria based on Andrews and Lu's (2001) procedure. In particular, the authors proposed three alternative criteria based on the moment selection criteria (MMSC). Namely, the MMSC-BIC (Bayesian information criterion) or the MMSC-HQIC (Hannan-Quinn information criterion). For our frameworks, we used the MMSC-BIC in order to determine the lag length (Andrews and Lu, 2001; Sigmund and Ferstl, 2021). The results reveal $w = 1$ for all frameworks.

In particular, the traditional panel approaches such as pooled ordinary least square, fixed, and random effect panel models are inappropriate and unable to efficiently estimate the results due to several issues such as lagged dependent variables, endogeneity of independent variables, country-specific effects, and error terms are not autocorrelated (Sigmund and Ferstl, 2021). Additionally, endogeneity is classical problem for panel data models and unveils biased and discrepant estimators. To overcome the endogeneity, many articles implement GMM framework (e.g. Wang and Lu, 2020; Lin et al., 2021; Opoku et al., 2021). However, this GMM framework still cannot completely trace the linkages between renewable energy consumption, emissions and

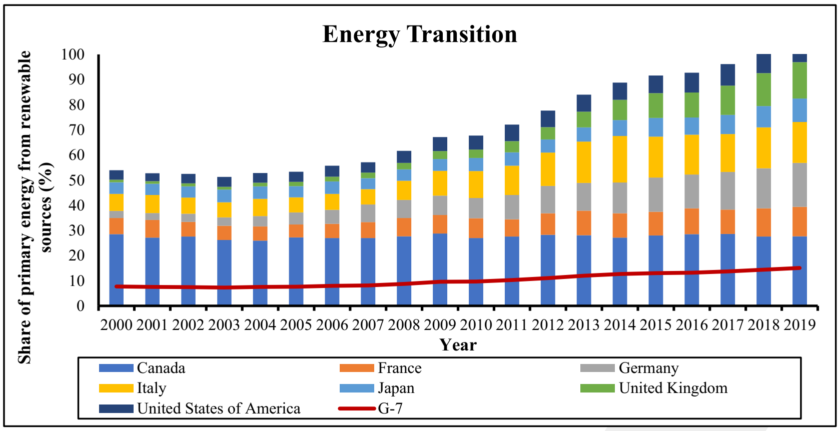

Fig. 1. Energy transition in G-7 countries.

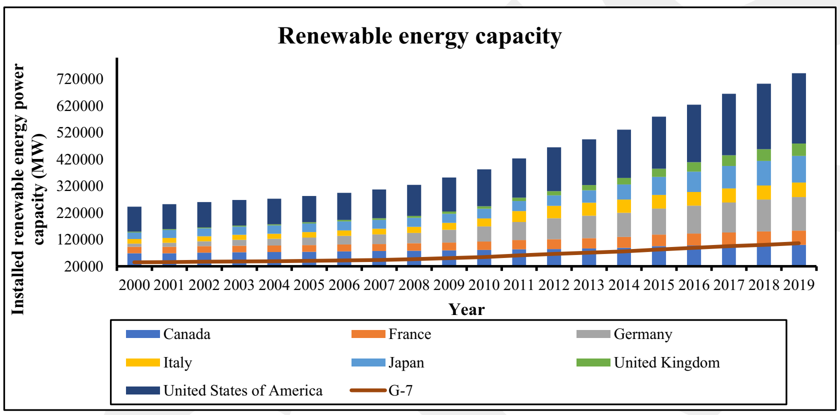

Fig. 2. Renewable energy capacity in G-7 countries

economic growth. According to relevant literature, there are possibly two-way associations among renewable energy consumption, emissions and economic growth (Apergis et al., 2010; Dogan and Seker, 2016). The GMM-PVAR model establishes a system of equations which includes all the variables as endogenous. Hence, this method can suitably eliminate the endogeneity problem. Furthermore, it can capture the leverage of one exogenous shock applying the orthogonalized response and keeping the other covariates invulnerable to external shocks (Sigmund and Ferstl, 2021). Other studies also applied a GMM-PVAR model, among others (Ouyang and Li, 2018; Ozcan et al., 2020; Gyedu et al., 2021; Usman et al., 2022).

4. Empirical analysis

4.1. Pre-estimation checks

In Table 2, the descriptive statistics for the sampled economies' series are depicted. For instance, the mean of RECAP is the largest, followed by GDP. On the other hand, KYOTO possesses the smallest mean among the modeled variables. Also, a significant oscillation between minimum and maximum values of the variables is noticed.

Table 2
Descriptive statistics.

Variables	Max	Min	Mean	Std. dev
ENTR	28.74	0.98	10.25	8.01
GDP	20,563.6	1290.4	4980.8	5095.4
CO_2	6134.5	315.9	1375.5	1792.7
FPR	223.52	61.55	130.45	44.16
RECAP	26,2732.5	2893.0	60,481.9	49,872.9
KYOTO	1	0	0.72	0.45

Table 3 shows the correlation among the selected series. ENTR demonstrates a significant and positive association with FPR and RECAP, while it shows a significantly negative correlation with GDP and CO_2. Besides, ENTR exhibits no significant correlation with KYOTO. Likewise, GDP indicates a significantly positive correlation with CO_2 and RECAP and negative correlation with KYOTO except FPR that is insignificant. The CO_2 correlation is significant only with RECAP and KYOTO that is positive and negative, respectively. Additionally, FPR possesses a positive correlation with RECAP and KYOTO. Lastly, RECAP shows a significantly negative correlation with KYOTO. Besides, the statistics of variance inflation factor (VIF) affirm that the multicollinearity level for GDO and CO_2 is moderate and can be problematic; therefore, a test that deals with endogeneity is required for reliable long-run analysis.

Next, we deploy Pesaran's (2004) test that asserts that the cross-sectional dependence (CD) is witnessed in the constructs of the current study at 1% significance level as Table 4, Panel A and C reports. It indicates the invalidity of the conventional tests and techniques on account of CD and suggests the application of advanced methods for reliable outcome. Therefore, the study uses the 2nd generation unit root tests (i.e., CADF and CIPS). The findings determine the stationary of all series at first difference, implying that the null hypothesis of unit root is rejected and all the variables are stationary in the presence of CD as reported in Table 4, Panel A.

Table 4, Panel B provides the cointegration results to confirm the long-run association among the selected series. The outcome of Kao (1999) and Westerlund (2007) tests reject the null hypothesis of "no cointegration" and accept the alternative hypothesis at 1% and 5%

Table 3
Correlation matrix and VIF statistics.

	ENTR	GDP	CO_2	FPR	RECAP	KYOTO
ENTR	1.00					
GDP	−0.36***	1.00				
CO_2	−0.28***	0.92***	1.00			
FPR	0.23***	0.05	−0.03	1.00		
RECAP	0.59***	0.47***	0.51***	0.23***	1.00	
KYOTO	0.07	−0.48***	−0.60***	0.27***	−0.33***	1.00
VIF		7.03	8.62	1.26	1.49	1.81

Notes: ***, **, and * show significance at a 1%, 5% and 10% level, respectively. VIF means variance inflation factors.

Table 4
Tests for panel unit root, cointegration and cross-sectional dependence.

Panel A: panel unit root tests			
Variables	CD-test	CADF (1st diff.)	CIPS (1st diff.)
lnENTR	15.68***	−3.36***	−5.51***
lnGDP	14.19***	−2.29*	−3.53***
$lnCO_2$	12.78***	−3.37***	−3.91***
lnFPR	20.49***	−2.61***	−2.61***
lnRECAP	19.69***	−2.31*	2.43**

Panel B: panel cointegration tests
Kao test with demean option: −6.18***
Westerlund test: −1.80**
Panel C: CD-test for the model
Pesaran CD test: 24.084***

Notes: ***, **, * show significance at a 1%, 5% and 10% levels, respectively.

Table 5
Results for the GMM-PVAR.

Dependent variable	lnENTR	lnGDP	$lnCO_2$
lnENTR (−1)	0.354***	0.340*	0.007
lnGDP (−1)	0.165*	0.012***	−0.003**
$lnCO_2$ (−1)	−0.123*	−0.106	0.011***
lnFPR	−0.315**	0.173	−0.474
lnRECAP	0.321***	0.536**	0.146
KYOTO	0.557*	−0.214*	0.346

Diagnostic tests	
Hansen J stat. *p*-value	0.925
(1) Modulus of eigenvalue	−0.408
(2) Modulus of eigenvalue	−0.243
(3) Modulus of eigenvalue	0.011

Note: ***, **, and * show significance at a 1%, 5% and 10% level, respectively.

significance level, respectively. The results indicate that the long-run association among ENTR, GDP, CO_2, FPR, and RECAP exists in the presence of CD. Hence, we can confidently move towards the next step of parameters estimation.

4.2. Evidence from the GMM-PVAR estimation

In this section, we compute long-run relationship among the energy transition and its determinants. Before interpreting the GMM-PVAR coefficients, it is imperative to assess the stability condition of GMM-PVAR (Usman et al., 2022). The stability condition's outcome reveals that modulus of eigenvalue's values are less than one, implying that PVAR fulfills the stability condition as Fig. 3 illustrates. It also ensures that all the modeled series and PVAR system are stationary. Thus, the GMM-PVAR estimates are reliable and consistent as Table 5 presents. Since the paramount focus of the study is divulging the determinants of (energy transition) ENTR, we mainly interpret how the modeled factors affect the ENTR. Besides, we find and discuss the several interesting and novel findings.

The GMM-PVAR estimates confirm the positive and significant link between RECAP and ENTR such that, on average, a 1% rise in RECAP tends to enhance the ENTR in G-7 economies by 0.32% at 1% significance level. It implies that the share of renewable energy (RE) to primary energy rapidly increases as G-7 economies improve the RE power capacity installation. Putting simply, the renewable energy technology significantly triggers the energy transition in G-7 nations. The likely explanation is that G-7 economies are among the top nations which are taking the serious measures to step up their renewable energy capacities in order to achieve green and sustainable development. To this end, G-7 economies have invested a large share of their GDPs to trigger the renewable energy production. For example, USA, Japan, UK, France, Germany, Canada and Italy have invested \$55.5bn, \$16.5bn, \$5.3bn,

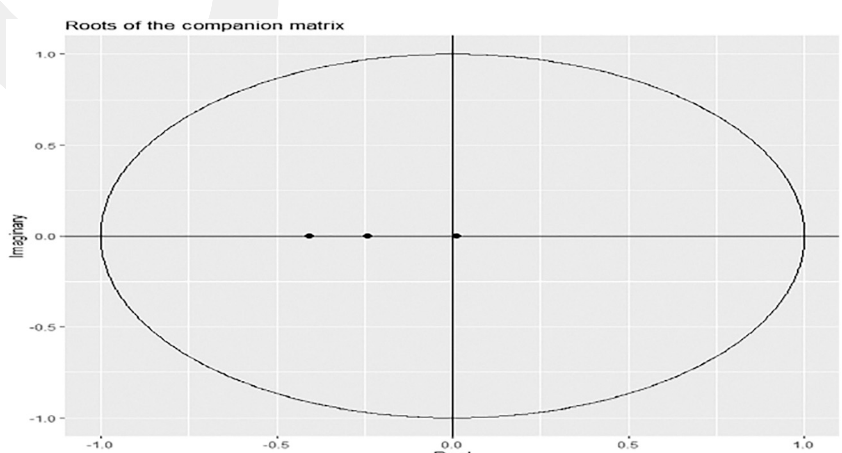

Fig. 3. Stability test.

$4.4bn, $4.4bn, $2bn, and $1.9bn to renewable energy industry in 2019 in order to enhance the RE power capacity installation (International Renewable Energy Agency, i.e., IRENA, 2021). Consequently, the renewable energy power capacity of the USA, Japan, Canada, Germany, Italy, France, and UK was recorded by 178.08GW, 117.21GW, 87.15GW, 69.80GW, 47.63GW, 38.72GW, and 35.64GW, respectively. Also, these economies were listed in the 10 economies with largest renewable energy power capacity. Besides, a large number of patents for renewable energy evolution were registered in G-7 nations. For example, 15,421 patents in USA, 343 patents in UK, 364 patents in Canada, 2464 patents in Japan, 2469 patents in Germany, 99 patents in France were registered in 2020 (IRENA, 2021). All such steps improve the renewable technology (i.e., renewable energy power capacity installation). Ultimately, this process boosts the renewable energy production that triggers the green energy transition ratio in G-7 economies. Unlike the prior studies, this is the unique outcome of the current study that asserts the RECAP as a novel determinant of ENTR since this is the first study that confirms the dynamic nexus between renewable energy production and green energy transition ratio in G-7 economies. Also, this outcome is more directional and reliable in the term of policy recommendations perspective because this finding is based on the advance econometric technique that tackles the issue of cross-sectional dependance and heterogeneity. Hence, the policy-makers can consider these results for policy-making perspective due to the presence of reliability, consistency, and unbiasedness, unlike the traditional econometric techniques.

Like RECAP, the environment-related policy, via, KYOTO has a positive impact on ENTR that is significant at 10% level of significance. It indicates that, on average, a 1% upsurge in the implication of the KYOTO protocol policies leads to boost the ratio of ENTR by 0.55%. The KYOTO protocol is based on such principles and policies that emphasize the advanced and industrialized economies to enhance the environmental quality by promoting the renewable energy resources and reducing the greenhouse gases. Practicing the KYOTO protocol principles, G-7 countries has taken remarkable steps by promoting the green infrastructure investment. For instance, the USA, Italy, Germany, France, Canada, Japan, and UK have invested £971.75bn (6.39% of GDP), £83.87bn (5.91% of GDP), £49.39bn (1.80% of GDP), £47.70bn (2.48% of GDP), £32.55bn (2.64% of GDP), £13.62bn (0.38% of GDP), and £12.13bn (0.60% of GDP), correspondingly, in 2020 (Trade Union Congress, 2021). Since the green infrastructure investment support the green environment through various means such as improving the green energy production and encouraging the green energy efficiency, thus, such steps under the umbrella of KYOTO protocol escalate the process of green energy transition. Again, this is another unique finding of our study that claims that KYOTO protocol principles effectively invigorate the energy transition in G-7 economies. In the context of the comparison, the prior literature does not focus on divulging the practical effects of KYOTO on green energy transition. Hence, this finding possesses the vital importance for policy-makers to induce the global authorities in order to take the serious steps to attain the green and sustainable development.

In a similar vein, GDP also shows a significantly positive link with ENTR. The findings determine that a 1% increase in G-7 economies' GDP results in fostering the ENTR level, on average, by 0.16% at 10 significance level. Since G-7 are the leading economies that invest a substantial part of their GDPs towards renewable energy industry for green environmental, hence, the variable of GDP demonstrates positive effects on ENTR. The same outcome is articulated by Nawaz et al. (2021) for N-11 and BRICS, Gozgor et al. (2020) for OECD, Jacqmin (2018) for EU, and Chen (2018) for China. Unlike the current finding, Aguirre and Ibikunle (2014) for 38 economies, Marques et al. (2010) for selected EU economies, and Omri and Nguyen (2014) for 64 economies confirm the adverse effects of GDP growth on the renewable energy consumption. The plausible reason for these contradicting results is that majority of the prior scholars rely on traditional technique to assess the impacts. Hence, these studies can be biased and misleading and therefore, this results in contradiction among the studies. Another possible reason is the inaccurate model selection. Since the inappropriate model selection may lead to misleading results that can be contradictive to the other studies.

Unlike the above variables, CO_2 emissions reduce the process of ENTR with the significance level of 10%. The results suggest that, on average, energy transition ratio declines by 0.12% as the level of emissions increases by 1%. It indicates that carbon emissions' detrimental repercussions deteriorate the renewable energy transition process in G-7 economies. The likely reason is that carbon emission mainly stems from the combustion of fossils fuels. It indicates that the more the use of fossil fuels tends to shrink the volume of green energy. Ultimately, it can be inferred that carbon emissions indirectly deteriorate the green energy transition process when more traditional fuels are employed. It can also be inferred from the above findings that the consistent use of fossils fuels in G-7 economies may create the adverse effects on the green energy transition process. Also, Ahmadov and van der Borg (2019) for EU economies conclude the same result. Contrary of our outcome, Gozgor et al. (2020), and Aguirre and Ibikunle (2014) affirm that positive association between CO_2 and renewable energy for OECD, EU and BRICS economies, respectively. Finally, FPR also reveals the negative link with ENTR with 5% significance level. It is found that a 1% rise in the prices of fossils fuel tends to impede the energy transition process, on average, by 0.31%. The likely economic reason is that the rise in FPR escalates the prices of the products that increase the producers' profit. To grab the high ratio of profits, the local producers prefer to deploy cheap technologies based on fossil fuels and this process decrease the use of green technology. Ultimately, it reduces the ENTR. The recent finding is in the line with the outcome reported by Ahmadov and van der Borg (2019) for EU economies and is contradictory with the study by Gozgor et al. (2020) for OECD.

Whereas the determinants of GDP are concerned, the GMM-PVAR estimates exhibit that ENTR is a significant determinant of G-7 economies such that a 1% increase in ENTR leads to foster the GDP ratio by 0.34% with the 10% significance level. Overall, it implies that ENTR has the significantly positive impacts on GDP. This is in line with Gozgor (2018). Likewise, RECAP also indicates a positive link with GDP. We notice that the level of GDP moves upwards by 0.53% due to an upsurge in RECAP by 1%. In this respect, Ram et al. (2020) concluded that renewable energy technologies generate socioeconomics benefits. Omri et al. (2022) overall stated that "Green energy sources will certainly have a leading role not only in the long-awaited process of decarbonization of the fuel mix but also in building a new economic model to advance social welfare and sustainability". On the other hand, KYOTO variables affect the GDP adversely such that a 1% increase in KYOTO results in shrinking the GDP by 0.21% with 10% level of significance. Ironically, FPR and RECAP demonstrate no significant link with the GDP of G-7 countries. As far as the determinants of CO_2 are concerned, we find that only one variable shows the significant nexus with CO_2. The results reveal that only GDP has the significant association with CO_2 such that a 1% rise in GDP leads to ameliorate the harmful effects of emissions by 0.003%. While the all-other series (ENTR, FPR, RECAP and KYOTO) show the insignificant relationship with CO_2.

4.3. *Evidence from conventional long-run estimations*

We also apply some conventional techniques to compare the findings with the outcome of novel GMM-PVAR model. According to Table 6, the OLS, Random effects, DOLS, FMOLS, and IMOLS estimates determine that a 1% upsurge in GDP tends to shrink the ENTR level by 0.73%, 0.50%, 0.88%, 1.00%, and 0.82%, respectively. These findings strongly oppose the outcome of GMM-PVAR. Likewise, FMOLS estimate suggest that a 1% rise in CO_2 significantly supports the process of ENTR by increasing it by 0.30%, against the GMM-PVAR estimate. However, OLS, and Random effects estimates support the finding of GMM-PVAR such that a 1% rise in CO_2 discourages the ENTR by 0.18% and 0.37%,

Table 6
Results from conventional long-run estimations.

Independent variables	OLS	Random effects	DOLS	FMOLS	IMOLS
lnGDP	−0.730***	−0.501**	−0.888***	−1.005***	−0.829***
	(0.101)	(0.213)	(0.174)	(0.189)	(0.261)
lnCO_2	−0.181***	−0.376***	0.011	0.306**	−0.074
	(0.111)	(0.134)	(0.145)	(0.142)	(0.257)
lnFPR	0.097***	0.044**	1.319***	0.355**	0.730*
	(0.034)	(0.019)	(0.310)	(0.152)	(0.408)
lnRECAP	0.856***	0.849***	0.838***	0.843***	0.878***
	(0.011)	(0.055)	(0.060)	(0.067)	(0.113)
lnKYOTO	−0.044*	−0.021	−0.029	0.133**	0.100
	(0.026)	(0.018)	(0.087)	(0.057)	(0.120)
Constant	3.168***	3.518***			
	(0.405)	(0.489)			
Year dummies	Yes	Yes			
Hausman test		6.894			
R-squared	0.968	0.960			

Notes: ***, **, and * show significance at a 1%, 5% and 10% level, respectively. Robust standard errors are shown in parentheses. Non-significant Hausman test unveils that Random effects model is preferred.

correspondingly, except DOLS and IMOLS estimates that are insignificant. In the case of FPR-ENTR nexus, OLS Random, effects, DOLS, FMOLS, and IMOLS estimates confirm that ENTR significantly escalate the ratio of ENTR by 0.09%, 0.04%, 1.31%, 0.35%, and 0.73%, respectively, contradicting with the GMM-PVAR estimate. Also, the estimate of OLS shows the adverse effects of KYOTO on ENTR such that a 1% rise in KYOTO tends to contract the ENTR by 0.04%, unlike the outcome of GMM-PVAR. However, the FMOLS estimate deduces that ENTR gets the rise by 0.13% as KYOTO increases by 1%, supporting the GMM-PVAR outcome. Lastly, all the conventional methods' outcome remains consistent with the GMM-PVAR results in the case of RECAP-ENTR nexus. We observe that OLS, Random effects, DOLS, FMOLS, and IMOLS estimates affirm that a 1% increase in RECAP results in enhancing the ratio of ENTR by 0.85%, 0.84%, 0.83%, 0.84% and 0.87%, respectively.

We observe that the conventional estimators contradict with the results of GMM-PVAR while exploring the nexus between GDP, CO_2, FPR, KYOTO and ENTR. The essential reason to report the results of conventional techniques is to demonstrate the notable difference between outcomes of both kinds of methods i.e., traditional and advanced econometric techniques. The traditional techniques cannot tackle the issue of endogeneity. In a similar vein, these techniques also cannot handle issue of cross-sectional dependance. Thus, the results based on the traditional techniques may be biased, inconsistent, and misleading; hence, such outcomes cannot be reliable to derive policy recommendations. On the other hand, the novel GMM-PVAR model has the strong ability to handle the issues endogeneity and CD among the selected series. For example, the conventional techniques indicate that GDP slows down the green energy transition process. Contrarily, GMM-PVAR estimates confirm that GDP is a vital indicator in triggering the green energy transition process. Similarly, we observe that the outcome of FMOLS technique suggests the positive association between CO_2 and energy transition, against the advanced estimator. Also, it can be seen that the conventional estimates show FPR enhance the ratio of energy transition. On the other hand, the advanced technique contradicts the conventional results and affirm the adverse effects of FPR on green energy. Besides, the findings of conventional methods exhibit that KYOTO variable deteriorates the green energy transition unlike the GMM-PVAR's results. To recapitulate, the conventional methods produce the contradictive results. Hence, our findings indicate that the conventional methods' results can be suspected for biasness and, thus, their outcome is contradictive with the GMM-PVAR estimates which are consistent and reliable. Besides, this comparison indicates how the misleading and inconsistent results can mislead the policy-makers regarding to suggest the relevant policies. Specially, these contradictive outcomes are severely critical and sensitive for G-7 economies in the context of policy implications. Hence, it is imperative to focus on the suitable and appropriate techniques to obtain the reliable findings for recommending the appropriate policies.

5. Conclusion and policy implications

By far, the recent study has extended the existing literature by identifying the two novel indicators of renewable energy transition (ENTR), i.e., RECAP as a renewable technology and KYOTO as an environmental policy for G-7 economies. To this end, the study takes the data from 2000 to 2019 and deploys novel GMM-PVAR technique that possesses the ability to handle the traditional as well as advanced econometric issues to obtain the robust findings. The results assert that RECAP and KYOTO are the crucial factors that significantly trigger the process of ENTR in G-7 economies. Hence, these both indicators can play an essential role to put the sampled economies on the track of energy transition for sustainable and green development. Additionally, GDP shows the positive effects, and CO_2 and FPR exhibit the adverse impacts on ENTR. We also notice that the conventional and traditional approaches that cannot tackle the advanced econometric issues compute the misleading and biased findings which can be highly sensitive for policy recommendations process.

Since the primary aim of the study to divulge the results in order to suggest the suitable policies; hence, we present some results-based policies to the pertinent authorities. Firstly, the results determine that RECAP significantly triggers the green energy transition in the G-7 nations. Although G-7 economies are listed in the leading economies that are endeavoring to replace the traditional energy with the green energy; however, this process suffers from several risk factors. Such kind of risks and uncertainties may impede the private investment ratio to the green energy sector. Also, the large amount of public investment for energy transition may lead to a fiscal burden. To cope with this situation, the recent study recommends a phase-wise policy. The first step should involve such a process in which G-7 economies will focus on importing the green technologies that enhance the green energy power installation via foreign direct investment route. This step will assist in boosting the renewable energy installation capacity without generating the fiscal burden. The second phase should consist of the process that helps in getting the stability for the first phase. To do so, the G-7 authorities should start to provide the subsidies to the green energy installation investors and levy the high ratio of taxes on the industries deploying the conventional and polluting methods for energy production. This step will bring a stable green energy power installation process. In the third phase, after getting the stability, the G-7 economies should consider to replace the cheap and polluting energy industries with the green energy industries via imports. Ultimately, this three-phase strategy may help in boosting the green energy installation process that will lead to increase the green energy transition in the sampled nations.

Secondly, we find that KYOTO, as an environmental policy variable, significantly promotes the energy transition. It indicates that the G-7 economies have successfully commenced to practice the KYOTO principles to obtain the clean energy (SDG-7). The G-7 economies are in the list of top emissions importer economies. For example, Germany, France, the USA, the UK, Japan, Italy, and Canada were the 2nd, 3rd, 5th, 8th, 9th, 11th, and 16th, respectively, top economies as a carbon importer in 2019 (WITS, 2021). This alarming situation necessitates to take more serious measures for G-7 economies. In this context, the G-7 economies should pay deep attention on the following two suggestions in order to foster the green energy industry while following the KYOTO protocol principles. Firstly, the G-7 nations should promote the green infrastructure program publicly. To this end, the authorities should focus on both sides of producers and consumers as well. For instance, the "Green Subsidies" and "Green Awards" programs can encourage the production of renewable energy; it will increase the energy transition. In a similar vein, the governments should induce the consumers' side to use the green products. It can put a pressure on the production side to deploy the green energy resources and this process can also enhance the green energy transition. Secondly, since the G-7 economies imports a huge quantity of carbon emitting goods, an appropriate amount of tax should be imposed on such goods. This step will discourage the imports of environmental polluting goods gradually along with increasing the finance. Such finance can be utilized for the promotion of the "Green Subsidies" and "Green Awards" to magnify the green energy transition under the umbrella of KYOTO protocol.

Finally, we notice that fossil fuel prices significantly discourage the process of energy transition in G-7 economies. It implies that the inflation in fossil fuels production can detract from energy transition and it may cause the instability in green energy industries. Therefore, it is suggested that the imposition of an appropriate tax ratio on the industries deploying the conventional energy system in the phase of inflation in an economy can minimize the adverse effects of the rise in fossil fuel prices and discourage the producers from replacing the green industry with cheap energy industry to earn the high profits.

For future studies, our study suggests the following direction, hoping that these directions can be helpful in divulging new research sights. Firstly, the recent study targets the G-7 economies while exploring the RECAP and KYOTO as novel drivers of energy transition. In future, the scholars are suggested to examine the same model for the sample of global economies, different regions (i.e., Asian region, South Asian region, Middle East region, European Union and African states), and various income-wise groups of economies (i.e., low-income, middle-income, and high-income nations) for the policy-oriented findings. Secondly, our study considers the linear characteristics of the sampled series. The researchers are encouraged to divulge the plausible nonlinearity among the modeled variables by deploying the nonlinear techniques for more detailed and informative results. Thirdly, our findings confirm the significant difference between the results of traditional and advanced econometric techniques. Hence, the scholars are suggested to be careful in selecting the suitable and advanced methods in order to obtain reliable and robust findings. Lastly, the future studies can enrich the recent study's model by including some other variables such as financial innovation, human capital, global value chain, economic globalization, financial assets' prices, economic policy uncertainties etc., expecting the interesting findings.

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. No funds, grants, or other support were received.

References

Ackah, I., Kizys, R., 2015. Green growth in oil producing African countries: a panel data analysis of renewable energy demand. Renew. Sust. Energ. Rev. 50, 1157–1166. https://doi.org/10.1016/j.rser.2015.05.030.

Afrifa, G.A., Tingbani, I., Yamoah, F., Appiah, G., 2020. Innovation input, governance and climate change: evidence from emerging countries. Technol. Forecast. Soc. Chang. 161, 120256 https://doi.org/10.1016/j.techfore.2020.120256.

Aguirre, M., Ibikunle, G., 2014. Determinants of renewable energy growth: a global sample analysis. Energy Policy 69, 374–384. https://doi.org/10.1016/j.enpol.2014.02.036.

Ahmadov, A.K., van der Borg, C., 2019. Do natural resources impede renewable energy production in the EU? A mixed-methods analysis. Energy Policy 126, 361–369.

Alam, M.M., Murad, M.W., 2020. The impacts of economic growth, trade openness and technological progress on renewable energy use in organization for economic co-operation and development countries. Renew. Energy 145, 382–390. https://doi.org/10.1016/j.renene.2019.06.054.

Andrews, D.W., Lu, B., 2001. Consistent model and moment selection procedures for GMM estimation with application to dynamic panel data models. J. Econ. 101 (1), 123–164.

Apergis, N., Payne, J.E., Menyah, K., Wolde-Rufael, Y., 2010. On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. Ecol. Econ. 69 (11), 2255–2260. https://doi.org/10.1016/j.ecolecon.2010.06.014.

Bamati, N., Raoofi, A., 2020. Development level and the impact of technological factor on renewable energy production. Renew. Energy 151, 946–955. https://doi.org/10.1016/j.renene.2019.11.098.

Bayale, N., Ali, E., Tchagnao, A.F., Nakumuryango, A., 2021. Determinants of renewable energy production in WAEMU countries: new empirical insights and policy implications. Int. J. Green Energy 18 (6), 602–614. https://doi.org/10.1080/15435075.2021.1875467.

Baye, R.S., Ahenkan, A., Darkwah, S., 2021. Renewable energy output in sub Saharan Africa. Renew. Energy 174, 705–714. https://doi.org/10.1016/j.renene.2021.01.144.

Belaïd, F., Elsayed, A.H., Omri, A., 2021. Key drivers of renewable energy deployment in the MENA Region: empirical evidence using panel quantile regression. Struct. Chang. Econ. Dyn. 57, 225–238. https://doi.org/10.1016/j.strueco.2021.03.011.

Bersalli, G., Menanteau, P., El-Methni, J., 2020. Renewable energy policy effectiveness: a panel data analysis across Europe and Latin America. Renew. Sust. Energ. Rev. 133, 110351 https://doi.org/10.1016/j.rser.2020.110351.

Binder, M., Hsiao, C., Pesaran, M.H., 2005. Estimation and inference in short panel vector autoregressions with unit roots and cointegration. Econ. Theory 21 (4), 795–837.

Bourcet, C., 2020. Empirical determinants of renewable energy deployment: a systematic literature review. Energy Econ. 85, 104563 https://doi.org/10.1016/j.eneco.2019.104563.

BP, B.P., 2021. BP Statistical Review of World Energy. BP, London.

Brunnschweiler, C.N., 2010. Finance for renewable energy: an empirical analysis of developing and transition economies. Environ. Dev. Econ. 15 (3), 241–274. https://doi.org/10.1017/S1355770X1000001X.

Cadoret, I., Padovano, F., 2016. The political drivers of renewable energies policies. Energy Econ. 56, 261–269. https://doi.org/10.1016/j.eneco.2016.03.003.

Chang, T.H., Huang, C.M., Lee, M.C., 2009. Threshold effect of the economic growth rate on the renewable energy development from a change in energy price: evidence from OECD countries. Energy Policy 37 (12), 5796–5802. https://doi.org/10.1016/j.enpol.2009.08.049.

Chen, Y., 2018. Factors influencing renewable energy consumption in China: an empirical analysis based on provincial panel data. J. Clean. Prod. 174, 605–615.

Chen, K., Ren, Z., Mu, S., Sun, T.Q., Mu, R., 2020. Integrating the Delphi survey into scenario planning for China's renewable energy development strategy towards 2030. Technol. Forecast. Soc. Chang. 158, 120157 https://doi.org/10.1016/j.techfore.2020.120157.

Chen, C., Pinar, M., Stengos, T., 2021. Determinants of renewable energy consumption: importance of democratic institutions. Renew. Energy 179, 75–83. https://doi.org/10.1016/j.renene.2021.07.030.

Corsatea, T.D., Giaccaria, S., Arántegui, R.L., 2014. The role of sources of finance on the development of wind technology. Renew. Energy 66, 140–149. https://doi.org/10.1016/j.renene.2013.11.063.

da Silva, P.P., Cerqueira, P.A., Ogbe, W., 2018. Determinants of renewable energy growth in sub-Saharan Africa: evidence from panel ARDL. Energy 156, 45–54. https://doi.org/10.1016/j.energy.2018.05.068.

Dincer, I., 2001. Environmental issues: ii-potential solutions. Energy Sources 23 (1), 83–92. https://doi.org/10.1080/00908310151092218.

Dogan, E., Seker, F., 2016. Determinants of CO_2 emissions in the European Union: the role of renewable and non-renewable energy. Renew. Energy 94, 429–439. https://doi.org/10.1016/j.renene.2016.03.078.

Dogan, E., Inglesi-Lotz, R., Altinoz, B., 2021. Examining the determinants of renewable energy deployment: does the choice of indicator matter? Int. J. Energy Res. 45 (6), 8780–8793. https://doi.org/10.1002/er.6413.

Ed Dlugokencky and Pieter Tans, NOAA/(ESRL), 2021. www.esrl.noaa.gov/gmd/ccgg/trends/ ((Last accessed): 06/12/2021).

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

Essletzbichler, J., 2012. Renewable energy technology and path creation: a multi-scalar approach to energy transition in the UK. Eur. Plan. Stud. 20 (5), 791–816. https://doi.org/10.1080/09654313.2012.667926.

Fisher-Vanden, K., Jefferson, G.H., Liu, H., Tao, Q., 2004. What is driving China's decline in energy intensity? Resour. Energy Econ. 26 (1), 77–97. https://doi.org/10.1016/j.reseneeco.2003.07.002.

Gallo, A.B., Simões-Moreira, J.R., Costa, H.K.M., Santos, M.M., Dos Santos, E.M., 2016. Energy storage in the energy transition context: a technology review. Renew. Sust. Energ. Rev. 65, 800–822. https://doi.org/10.1016/j.rser.2016.07.028.

Gan, J., Smith, C.T., 2011. Drivers for renewable energy: a comparison among OECD countries. Biomass Bioenergy 35 (11), 4497–4503. https://doi.org/10.1016/j.biombioe.2011.03.022.

Gozgor, G., 2018. A new approach to the renewable energy-growth nexus: evidence from the USA. Environ. Sci. Pollut. Res. 25 (17), 16590–16600. https://doi.org/10.1007/s11356-018-1858-9.

Gozgor, G., Lau, C.K.M., Lu, Z., 2018. Energy consumption and economic growth: new evidence from the OECD countries. Energy 153, 27–34. https://doi.org/10.1016/j.energy.2018.03.158.

Gozgor, G., Mahalik, M.K., Demir, E., Padhan, H., 2020. The impact of economic globalization on renewable energy in the OECD countries. Energy Policy 139, 111365. https://doi.org/10.1016/j.enpol.2020.111365.

Gyedu, S., Heng, T., Ntarmah, A.H., He, Y., Frimppong, E., 2021. The impact of innovation on economic growth among G7 and BRICS countries: a GMM style panel vector autoregressive approach. Technol. Forecast. Soc. Chang. 173, 121169 https://doi.org/10.1016/j.techfore.2021.121169.

Holtz-Eakin, D., Newey, W., Rosen, H.S., 1988. Estimating vector autoregressions with panel data. Econ. J. Econ. Soc. 1371–1395.

Ibrahiem, D.M., Hanafy, S.A., 2021. Do energy security and environmental quality contribute to renewable energy? The role of trade openness and energy use in North African countries. Renew. Energy 179, 667–678. https://doi.org/10.1016/j.renene.2021.07.019.

Igliński, B., Iglińska, A., Cichosz, M., Kujawski, W., Buczkowski, R., 2016. Renewable energy production in the Łódzkie Voivodeship. The PEST analysis of the RES in the voivodeship and in Poland. Renew. Sust. Energ. Rev. 58, 737–750. https://doi.org/10.1016/j.rser.2015.12.341.

International Energy Agency (IEA), 2021. Achieving Net Zero Electricity Sectors in G7 Members. https://www.iea.org/reports/achieving-net-zero-electricity-sectors-in-g7-members.

International Renewable Energy Agency, 2021. https://www.irena.org/publications/2021/March/Renewable-Capacity-Statistics-2021.

IRENA (International Renewable Energy Agency), 2020. Global renewables outlook: energy transformation 2050. ISBN 978-92-9260-238-3. www.irena.org/publications.

Jacqmin, J., 2018. The role of market-oriented institutions in the deployment of renewable energies: evidences from Europe. Appl. Econ. 50 (2), 202–215. https://doi.org/10.1080/00036846.2017.1332749.

Jiahua, P., Guiyang, Z., Yan, Z., ShouXian, Z., Qianyi, X., 2010. Clarification of the concept of low-carbon economy and analysis of its core elements [J]. Int. Econ. Rev. 4, 88–102.

Jiang, S., Deng, X., Liu, G., Zhang, F., 2021. Climate change-induced economic impact assessment by parameterizing spatially heterogeneous CO_2 distribution. Technol. Forecast. Soc. Chang. 167, 120668 https://doi.org/10.1016/j.techfore.2021.120668.

Kao, C., 1999. Spurious regression and residual-based tests for cointegration in panel data. J. Econ. 90 (1), 1–44.

Karacan, R., Mukhtarov, S., Barış, İ., İşleyen, A., Yardımcı, M.E., 2021. The impact of oil price on transition toward renewable energy consumption? Evidence from Russia. Energies 14 (10), 2947. https://doi.org/10.3390/en14102947.

Khuong, P.M., McKenna, R., Fichtner, W., 2019. Analyzing drivers of renewable energy development in Southeast Asia countries with correlation and decomposition methods. J. Clean. Prod. 213, 710–722. https://doi.org/10.1016/j.jclepro.2018.12.192.

Koçak, E., Şarkgüneşi, A., 2017. The renewable energy and economic growth nexus in Black Sea and Balkan countries. Energy Policy 100, 51–57. https://doi.org/10.1016/j.enpol.2016.10.007.

Le, T.H., Nguyen, C.P., Park, D., 2020. Financing renewable energy development: insights from 55 countries. Energy Res. Soc. Sci. 68, 101537 https://doi.org/10.1016/j.erss.2020.101537.

Lee, J., Yang, J.S., 2019. Global energy transition and political systems. Renew. Sust. Energ. Rev. 115, 109370 https://doi.org/10.1016/j.rser.2019.109370.

Lin, B., Omoju, O.E., 2017. Focusing on the right targets: economic factors driving non-hydro renewable energy transition. Renew. Energy 113, 52–63. https://doi.org/10.1016/j.renene.2017.05.067.

Lin, W.L., Ho, J.A., Sambasivan, M., Yip, N., Mohamed, A.B., 2021. Influence of green innovation strategy on brand value: the role of marketing capability and R&D intensity. Technol. Forecast. Soc. Chang. 171, 120946 https://doi.org/10.1016/j.techfore.2021.120946.

Liu, W., Zhang, X., Feng, S., 2019. Does renewable energy policy work? Evidence from a panel data analysis. Renew. Energy 135, 635–642. https://doi.org/10.1016/j.renene.2018.12.037.

Lu, W.C., 2017. Renewable energy, carbon emissions, and economic growth in 24 Asian countries: evidence from panel cointegration analysis. Environ. Sci. Pollut. Res. 24 (33), 26006–26015. https://doi.org/10.1007/s11356-017-0259-9.

Lucas, J.N.V., Francés, G.E., González, E.S.M., 2016. Energy security and renewable energy deployment in the EU: liaisons dangereuses or virtuous circle? Renew. Sust. Energ. Rev. 62, 1032–1046. https://doi.org/10.1016/j.rser.2016.04.069.

Marques, A.C., Fuinhas, J.A., 2011. Drivers promoting renewable energy: a dynamic panel approach. Renew. Sust. Energ. Rev. 15 (3), 1601–1608. https://doi.org/10.1016/j.rser.2010.11.048.

Marques, A.C., Fuinhas, J.A., 2012. Are public policies towards renewables successful? Evidence from European countries. Renew. Energy 44, 109–118. https://doi.org/10.1016/j.renene.2012.01.007.

Marques, A.C., Fuinhas, J.A., Manso, J.P., 2010. Motivations driving renewable energy in European countries: a panel data approach. Energy Policy 38 (11), 6877–6885. https://doi.org/10.1016/j.enpol.2010.07.003.

Menegaki, A.N., 2011. Growth and renewable energy in Europe: a random effect model with evidence for neutrality hypothesis. Energy Econ. 33 (2), 257–263. https://doi.org/10.1016/j.eneco.2010.10.004.

Menegaki, A.N., Ozturk, I., 2016. Renewable energy, rents and GDP growth in MENA countries. Energy Sources Part B Econ. Plan. Policy 11 (9), 824–829. https://doi.org/10.1080/15567249.2014.949392.

Miremadi, I., Saboohi, Y., Arasti, M., 2019. The influence of public R&D and knowledge spillovers on the development of renewable energy sources: the case of the Nordic countries. Technol. Forecast. Soc. Chang. 146, 450–463.

Mukhtarov, S., Mikayilov, J.I., Maharramov, S., Aliyev, J., Suleymanov, E., 2022a. Higher oil prices, are they good or bad for renewable energy consumption: the case of Iran? Renew. Energy. https://doi.org/10.1016/j.renene.2021.12.135.

Mukhtarov, S., Yüksel, S., Dinçer, H., 2022b. The impact of financial development on renewable energy consumption: evidence from Turkey. Renew. Energy. https://doi.org/10.1016/j.renene.2022.01.061.

Nawaz, M.A., Seshadri, U., Kumar, P., Aqdas, R., Patwary, A.K., Riaz, M., 2021. Nexus between green finance and climate change mitigation in N-11 and BRICS countries: empirical estimation through difference in differences (DID) approach. Environ. Sci. Pollut. Res. 28 (6), 6504–6519.

Omri, A., Nguyen, D.K., 2014. On the determinants of renewable energy consumption: international evidence. Energy 72, 554–560. https://doi.org/10.1016/j.energy.2014.05.081.

Omri, A., Omri, H., Slimani, S., Belaid, F., 2022. Environmental degradation and life satisfaction: do governance and renewable energy matter? Technol. Forecast. Soc. Chang. 175, 121375.

Opoku, E.E.O., Kufuor, N.K., Manu, S.A., 2021. Gender, electricity access, renewable energy consumption and energy efficiency. Technol. Forecast. Soc. Chang. 173, 121121 https://doi.org/10.1016/j.techfore.2021.121121.

Ouyang, Y., Li, P., 2018. On the nexus of financial development, economic growth, and energy consumption in China: new perspective from a GMM panel VAR approach. Energy Econ. 71, 238–252. https://doi.org/10.1016/j.eneco.2018.02.015.

Ozcan, B., Tzeremes, P.G., Tzeremes, N.G., 2020. Energy consumption, economic growth and environmental degradation in OECD countries. Econ. Model. 84, 203–213. https://doi.org/10.1016/j.econmod.2019.04.010.

Papież, M., Śmiech, S., Frodyma, K., 2018. Determinants of renewable energy development in the EU countries. A 20-year perspective. Renew. Sust. Energ. Rev. 91, 918–934. https://doi.org/10.1016/j.rser.2018.04.075.

Pesaran, M.H., 2004. General Diagnostic Tests for Cross Section Dependence in Panels. In: CESifo Working Paper Series, p. 1229.

Pesaran, M.H., 2007. A simple panel unit root test in the presence of cross-section dependence. J. Appl. Econ. 22 (2), 265–312.

Pfeiffer, B., Mulder, P., 2013. Explaining the diffusion of renewable energy technology in developing countries. Energy Econ. 40, 285–296. https://doi.org/10.1016/j.eneco.2013.07.005.

Polcyn, J., Us, Y., Lyulyov, O., Pimonenko, T., Kwilinski, A., 2022. Factors influencing the renewable energy consumption in selected European countries. Energies 15 (1), 108. https://doi.org/10.3390/en15010108.

Popp, D., Hascic, I., Medhi, N., 2011. Technology and the diffusion of renewable energy. Energy Econ. 33 (4), 648–662. https://doi.org/10.1016/j.eneco.2010.08.007.

Przychodzen, W., Przychodzen, J., 2020. Determinants of renewable energy production in transition economies: a panel data approach. Energy 191, 116583. https://doi.org/10.1016/j.energy.2019.116583.

Rahman, S.M., Dinar, A., Larson, D.F., 2010. Diffusion of Kyoto's clean development mechanism. Technol. Forecast. Soc. Chang. 77 (8), 1391–1400. https://doi.org/10.1016/j.techfore.2010.03.001.

Ram, M., Aghahosseini, A., Breyer, C., 2020. Job creation during the global energy transition towards 100% renewable power system by 2050. Technol. Forecast. Soc. Chang. 151, 119682.

Ritchie, H., Roser, M., 2020a. Energy. Published at. https://ourworldindata.org/renewable-energy.

Ritchie, H., Roser, M., 2020b. CO_2 and greenhouse gas emissions. Published at. https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions.

Sadorsky, P., 2009. Renewable energy consumption, CO_2 emissions and oil prices in the G7 countries. Energy Econ. 31 (3), 456–462. https://doi.org/10.1016/j.eneco.2008.12.010.

Salehnia, N., Alavijeh, N.K., Salehnia, N., 2020. Testing porter and pollution haven hypothesis via economic variables and CO_2 emissions: a cross-country review with panel quantile regression method. Environ. Sci. Pollut. Res. 27 (25), 31527–31542. https://doi.org/10.1007/s11356-020-09302-1.

Salim, R.A., Rafiq, S., 2012. Why do some emerging economies proactively accelerate the adoption of renewable energy? Energy Econ. 34 (4), 1051–1057. https://doi.org/10.1016/j.eneco.2011.08.015.

Samour, A., Baskaya, M., Tursoy, T., 2022. The impact of financial development and FDI on renewable energy in the UAE: a path towards sustainable development. Sustainability 14 (3), 1208. https://doi.org/10.3390/su14031208.

Schill, W.P., 2020. Electricity storage and the renewable energy transition. Joule 4 (10), 2059–2064. https://doi.org/10.1016/j.joule.2020.07.022.

Sequeira, T.N., Santos, M.S., 2018. Renewable energy and politics: a systematic review and new evidence. J. Clean. Prod. 192, 553–568. https://doi.org/10.1016/j.jclepro.2018.04.190.

Sigmund, M., Ferstl, R., 2021. Panel vector autoregression in R with the package panelvar. Quarterly Rev. Econ. Finance 80, 693–720. https://doi.org/10.1016/j.qref.2019.01.001.

Tollefson, J., 2020. How hot will Earth get by 2100? Nature 580 (7804), 443–446. https://doi.org/10.1038/d41586-020-01125-x.

Tolliver, C., Keeley, A.R., Managi, S., 2020. Policy targets behind green bonds for renewable energy: do climate commitments matter? Technol. Forecast. Soc. Chang. 157, 120051.

Trade Union Congress, 2021. https://www.tuc.org.uk/research-analysis/reports/ranking-g7-green-recovery-plans-and-jobs.

UNFCCC, 2010. The mechanisms under the Kyoto Protocol: emissions trading, the clean development mechanism and joint implementation. http://unfccc.int/kyoto_protocol/mechanisms/items/1673.php.

Urom, C., Abid, I., Guesmi, K., Ndubuisi, G., 2021. Renewable energy consumption, globalization, and economic growth shocks: evidence from G7 countries. J. Int. Trade Econ. Develop. 1–29. https://doi.org/10.1080/09638199.2021.1961845.

Usman, O., Alola, A.A., Saint Akadiri, S., 2022. Effects of domestic material consumption, renewable energy, and financial development on environmental sustainability in the EU-28: evidence from a GMM panel-VAR. Renew. Energy 184, 239–251.

Uzar, U., 2020. Political economy of renewable energy: does institutional quality make a difference in renewable energy consumption? Renew. Energy 155, 591–603. https://doi.org/10.1016/j.renene.2020.03.172.

Wang, C., Lu, Y., 2020. Can economic structural change and transition explain cross-country differences in innovative activity? Technol. Forecast. Soc. Chang. 159, 120194 https://doi.org/10.1016/j.techfore.2020.120194.

Wang, Q., Li, S., Pisarenko, Z., 2020. Heterogeneous effects of energy efficiency, oil price, environmental pressure, R&D investment, and policy on renewable energy—evidence from the G20 countries. Energy 209, 118322. https://doi.org/10.1016/j.energy.2020.118322.

Westerlund, J., 2007. Testing for error correction in panel data. Oxf. Bull. Econ. Stat. 69 (6), 709–748.

World Bank, 2020. World development indicators. Available at, The World Bank. https://data.worldbank.org/. (Accessed 31 December 2020).

World Integrated Trade Solution, 2021. https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2019/tradeflow/Imports/partner/WLD/product/281121#:~:text=In%202019%2C%20Top%20importers%20of,18%2C540.26K%20%2C%20124%2C586%2C000%20Kg.

Xu, X., Wei, Z., Ji, Q., Wang, C., Gao, G., 2019. Global renewable energy development: influencing factors, trend predictions and countermeasures. Resources Policy 63, 101470. https://doi.org/10.1016/j.resourpol.2019.101470.

Zhao, Z.Y., Chen, Y.L., Li, H., 2019. What affects the development of renewable energy power generation projects in China: ISM analysis. Renew. Energy 131, 506–517. https://doi.org/10.1016/j.renene.2018.07.063.

Eyup Dogan is currently working as an Associate Professor of Economics in the Department of Finance & Economics at University of Sharjah, UAE. In addition, he serves as Editor for Environmental Science and Pollution Research, Associate Editor for Resources Policy and Guest Editors for Renewable Energy and Energy & Environment. He received his Ph.D. in Economics from Clemson University, USA, in 2014. His fields of interest are sustainable development, energy economics and environmental economics in which the relationship among macro-variables of the economy, energy consumption and environmental indicators are investigated. He has published around 45 articles at high-ranked international journals, received around 4900 citations and attended a number of international conferences.

Muhammad Zubair Chishti is currently working as PhD scholar in School of Business at Zhengzhou University, China. In addition, he is working as a visiting lecturer of Economics at the University of Chakwal, Pakistan. His major areas of research interests include environmental economics, international trade and tourism and poverty. He has published around 20 articles at high-ranked international journals and received above 300 citations.

Nooshin Karimi Alavijeh is currently working as a Postdoctoral Research Fellow and Lecturer at Ferdowsi University of Mashhad of Iran. Her major areas of research interests include energy economics, environmental economics, climate change. She has published around 13 articles at national and international journals.

Panayiotis Tzeremes is currently working in Department of Accounting and Finance at University of Thessaly, Greece. His major areas of research interests include energy economics, environmental economics, applied econometrics and resources policy. He has published around 40 articles at refereed top journals and received above 500 citations, and attended numerous national and international conferences.