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The study of renewable energy and economic development

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Abstract

Purpose – This paper aims to examine the factors influencing renewable energy output.

Design/methodology/approach – The panel data model was used to analyze the fixed and random effects.

Findings – The results showed that economic development, environmental-related technology patents, renewable energy consumption and the publication of papers and periodicals contributed to enhancing renewable energy production. Wind power generation's adjustment speed is faster than that of solar power generation in the renewable energy sector. The use of renewable energy was affected by the weather and related costs.

Originality/value – Many countries choose energy with reasonable prices and stable power generation and use renewable energy as additional backup power.

Keywords Green environment, Economic development, Renewable energy

Paper type Research paper

1. Introduction

Since the industrial revolution, human beings have begun to use many fossil fuels, resulting in a rapid increase in carbon emissions. The continued progress of science and technology and greenhouse gas emissions are increasingly uncontrolled. The third session of the Conference of the Parties was held in Kyoto, Japan, in 1997, and the Kyoto Protocol was approved to solve the problems like global warming, sea-level rise and climate extremes. It is the first international convention that specifically promotes the reduction of greenhouse gas emissions.

At present, the most important alternative energy is renewable energy. The International Energy Agency divides renewable energy into three categories: the first is waterpower; the second is solar energy, geothermal energy, wind power, tide, etc. The third is biomass energy. The proportion of developed countries adopting the second type of renewable energy is higher than that of developing countries because the treatment of this energy needs relatively high technology. The utilization rate of biomass energy in developing countries is higher than in developed countries because the technical threshold for using biological tissue or excreta as fuel is relatively low.

In addition, Apergis and Payne (2010) analyzed the direct correlation between real gross domestic product (GDP) and the amount of alternative energy generated. Lin and Li (2011) showed that carbon taxes not only promote renewable energy use and improve energy efficiency but also reduce energy consumption. Withana *et al.* (2013) suggested that renewable energy appeared to increase due to reduced fuel consumption. Goh *et al.* (2014) revealed that government policies, renewable energy investing plan, energy demand, geographical location and fund management are relevant standards affecting renewable energy power generation development.

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Lopes (2014) simulated the environmental, economic and employment impacts of past environmental tax reforms and found that fossil fuel consumption was affected by carbon and energy taxes. Perticas *et al.* (2017) proved that GDP has a massive impact on renewable energy and that GDP growth will stimulate the production of nonpolluting alternative energy sources, which means less burning fossil fuels. Damette and Marques (2019) found a significant negative correlation between carbon dioxide emissions and renewable energy production. They evidenced that the government decided to increase the share of renewable energy in electricity production because of environmental problems.

However, most of the studies on renewable energy were based on GDP, and the results showed that GDP growth would increase renewable energy. In addition, carbon tax and fuel consumption will also affect the growth of renewable energy. However, the relationship between technical factors and life satisfaction and renewable energy policies is seldom addressed.

The purpose of this study is threefold. It explores the economic factors that affect renewable energy production and provides governments with the direction of energy policy development in the future. It examines whether governments' relevant green environmental policies effectively produce renewable energy based on the population, country and education differences. Finally, it examines the speed adjustment for both renewable energy utilization based on fixed and random effects methods.

The results show that GDP, innovation in environmental technologies, general government final consumption expenditure, renewable energy consumption, scientific and technical journal articles number correlates significantly positively with renewable energy production. Environmental tax revenues, current health expenditures, industrial added value and traditional energy have significant negative effects on renewable energy production. The results revealed that weather conditions and associated costs would impact the use of renewable energy. Solar energy specifications are higher than the wind power connection among the adjustment coefficients, with a higher population and a larger education index. It indicates that policymakers can effectively use associated environmental policies to rapidly increase renewable energy production.

This study is organized as follows. Section 2 covers literature review, and Section 3 presents a brief description of data sources and methodology. Section 4 shows the results. Finally, Section 5 presents the conclusion and implications.

2. Literature review

The trade-off between economic growth and the environment can be illustrated by the production possibilities frontier curve in economics, which shows that with the increase of people's demand, nonrenewable resources will decrease. The most typical theory between economic growth and the environment is the environmental Kuznets curve (EKC). In the context of economic development, pollutants tend to rise first and then decline when a country's level of economic development is weak. Stern (2004) found the level of environmental pollution to be fairly low. The environmental quality gradually improves, so it presents an inverted U-shaped curve (Grossman and Krueger, 1995). Moreover, Beckerman (1992) found a strong correlation between economic growth and the environment, showing that economic development and wealth growth are the most reliable way to solve environmental problems.

The limit theory considered the possibility of violating the environmental threshold before the economic growth reached the turning point of the EKC. According to the theory of competition, Stern (2004) discussed the possible further relationship between economic growth and the environment under international competition. It showed that little attention had been paid to the environment in the early stages of economic growth. International competition has aggravated environmental damage until developed countries reduce their impact on the environment.

Andersen *et al.* (2007) and Lin and Li (2011) found that the higher the tax rate, the greater the greenhouse gas emission reduction. Sterner and Lozada (2009) mentioned that using some green taxes directly impacted reducing emissions and increasing overall economic output.

Bernauer and Koubi (2006) indicated that the increase in government spending as a share of GDP is related to air pollution, not affected by government quality control. López and Palacios (2010) studied the effect of government expenditure and environmental taxes on environmental quality in Europe, showing that total government expenditure is an essential determinant of air pollution. López *et al.* (2011) provided a theoretical basis for determining the impact of government expenditure on pollution. They found that redistributing government expenditure components to social and public goods can reduce pollution.

Goh *et al.* (2014) found that government policies, renewable energy investment, energy demand, geographical location and management of funds are a necessary standard that impacts renewable energy generation. Leuschner (2014) took China as a sample and used fixed-effect models to analyze further the relationship between the percentage of hydropower production and GDP per capita. The results concluded a positive and significant relationship between GDP per capita and the percentage of hydropower production. With GDP growth per capita, hydropower was growing faster than other energy sources.

Lan *et al.* (2012) analyzed the role of foreign direct investment (FDI), revealing the increase of FDI accompanied by pollution or environmental deterioration in host countries. Shahbaz *et al.* (2014a) also found that FDI worsened the world environment. Mert and Bölük (2016) focused on the relationship among greenhouse gas emissions, income levels, renewable energy and fossil energy and FDI. Sarkodie and Strezov (2019) showed that FDI inflows increase the carbon emissions from fuel combustion in developing countries. Hanif *et al.* (2019) examined the effects of fossil energy consumption and FDI on carbon emissions in 15 developing Asian countries. They found that FDI may cause environmental pollution. Mert *et al.* (2019) indicated fossil energy consumption and FDI inflows had worsened pollution levels across the The European Union (EU).

In recent decades, the impact of industrialization on carbon dioxide emissions has been extensively studied. Many studies use decomposition and decoupling analysis to analyze carbon emissions in the industrial sector. Shahbaz and Lean (2012) and Shahbaz *et al.* (2014b) found a positive correlation between industrialization and carbon dioxide emissions. Zhongping *et al.* (2011) established an error correction model for carbon emissions in China under a heavy industry structure (HIS). It was found that the formation and development of HIS played a positive role in promoting carbon emissions. Jeong and Kim (2013) conducted a decomposition analysis of greenhouse gas emissions from Korea's industrial manufacturing industry and found that structural effects played the greatest role in reducing greenhouse gas emissions. Li and Xia (2013) and Zhou *et al.* (2013) concluded that industrialization is one of the most critical factors affecting carbon dioxide emissions in China.

Ouyang and Lin (2015) found that the energy intensity of China's industrial sector is the main factor in reducing carbon dioxide emissions, while industrial activities are the main factor affecting the increase of industrial carbon dioxide emissions. The energy structure and carbon intensity of energy use will have a negative impact on the increase of carbon dioxide emissions. Liu *et al.* (2015) found that energy intensity was the main factor in reducing carbon intensity. Lin and Long (2016) carried out a decomposition analysis and examined the driving factors of carbon emissions change in China's chemical industry. They indicated that output per capita and industrial economy scale are the driving forces of carbon emissions increase. Raheem and Ogebe (2017) found that industrialization and urbanization influenced Africa's environmental degradation and income per capita.

In the past, Cheng *et al.* (2018) and Sinha and Shahbaz (2018) found that nonfossil energy helps reducing carbon dioxide emissions. However, Jebli and Youssef (2017) and Hu *et al.* (2018) believed that increasing renewable energy consumption would increase carbon dioxide emissions. Sterpu *et al.* (2018) and Sarkodie and Strezov (2019) showed that the increase of total energy consumption leads to the increase of greenhouse gases while increasing renewable energy consumption leads to the decrease of greenhouse gas emissions.

Brunnermeier and Cohen (2003) analyzed the determinants of environmental, technological innovation in the USA. It is found that the number of environmental-related patents increases with the rise of pollution reduction expenditure. To study the impact of technological improvements on reducing energy intensity, Voigt *et al.* (2014) and Wurlod and Noailly (2018) indicated that environmental patents could improve energy efficiency and thus reduce carbon emissions. Mensah *et al.* (2018) mentioned that innovation was critical to reducing carbon dioxide emissions in 28 organization for economic cooperation and development (OECD) countries. Cheng *et al.* (2019) revealed that the development of environmental patents has accelerated carbon emissions per capita.

Considering the role of environmental regulations in the verification of the pollution shelter hypothesis, Mert *et al.* (2019) investigated the relationship between carbon dioxide emissions, GDP, renewable and nonrenewable energy use and FDI inflows in European countries. Using ordinary least squares (OLS) and quantile regression methods, Cheng *et al.* (2019) explored the impact of renewable energy, environmental patents, economic growth and other variables on carbon dioxide emissions per capita in Brazil, Russia, India, China, South Africa countries. The results showed that the supply of renewable energy and foreign direct investment reduced carbon dioxide emissions per capita, and the development of environmental patents accelerated carbon emissions per capita. In addition, exports GDP per capita increased carbon dioxide emissions per capita, having an asymmetric inverted U-shaped impact. The results confirmed that economic growth led to energy consumption and FDI inflows, having a significant long-term causality for carbon emissions.

In the past, people took economic development as their primary goal. After the middle of the 20th century, the rapid development of human social and economic activities was driven by the progress of science and technology. People's lifestyles also developed in mass production, mass consumption and mass abandonment with the abundance of material life, resulting in the impact of business process on the environment beyond its natural recovery ability. As a result, many severe environmental and social problems, such as global climate anomaly, environmental pollution and sharp reduction of resources, have been caused and threaten human beings' safety and future generations. International organizations of relevant units have begun to pay attention to this phenomenon.

As a result of the changes in global climate and environment and air pollution caused by overexploitation, people's quality of life has declined sharply. Diener (2006) emphasized the quality of life, which is usually related to external factors, such as environmental factors and income. MacKerron and Mourato (2009) surveyed Londoners and showed that perceived and actual pollution are related to happiness. Environmental quality made people happy, and environmental deterioration made people sad. The study also highlighted the impact of climate, noise and air quality. Understanding environmental issues such as air pollution and its adverse impacts on humans and ecosystems may directly reduce individual life satisfaction.

Beja (2012) used Latin American respondents as samples. The results showed that respondents perceived poor local air quality, which reduced their well-being. Silva and Brown (2013) found that respondents believed noise and lack of green space environment associated with a significant negative impact on life satisfaction, while urban environment had a significant positive impact on life satisfaction. Goetzke and Rave (2015) indicated that the correlation between air pollution and well-being is low. However, the actual measurement results showed a substantial correlation between air pollution and well-being. Levinson (2018) used different welfare and pollution measures to measure the negative correlation between happiness and pollution in different countries.

Mazzoleni and Nelson (2007) revealed that globalization plays an essential role in disseminating scientific knowledge. Weber (2011) focused on scientific publications related to the knowledge economy (KE) and found a strong relationship between KE and long-term economic prosperity for many influential companies. In terms of absolute and conditional catch-up models, Asongu and Nwachukwu (2016) noted that advanced countries contribute and dominate scientific knowledge continually.

Previous papers did not address the impact of population, country and education differences on the efficiency of renewable energy policies, nor did they study the relevance of adjustment coefficients. This study will estimate the current global climate and environment and then use the empirical model to analyze renewable energy production's economic factors.

3. Data and research methods

This study uses the top 80 countries in the 2018 Global Best Country Ranking Survey conducted by the *U.S. News & World Report* on renewable energy production. This study screens some countries due to the lack of data. Finally, only 32 countries are selected as samples, as shown in Table 1 below. From 2007 to 2016, the total output of solar power generation and wind power generation in each country was taken as alternative variables for renewable energy production. Sources are UNDATA, United Nations Framework Convention on Climate Change, The World Bank and OECD. Sources are international organization databases and major data websites listed in Table 2.

3.1 Research hypotheses

This study explores the key factors affecting renewable energy production. The following hypotheses are deduced according to the previous literature.

Australia	Austria	Bulgaria	Canada
Costa Rica	Croatia	Czech Republic	Denmark
Finland	France	Germany	Greece
Hungary	Ireland	Italy	Japan
Latvia	Luxembourg	The Netherlands	New Zealand
Norway	Poland	Portugal	Romania
Russia	Slovenia	Spain	Sweden
Switzerland	Ukraine	UK	USA

Source: Sort by initials of country names

Table 1. Country list of study samples

Table 2. Sources and definition

Source of data	Unit	Definition of data	Name of data
Solar power generation	Kilowatt-hours, million	Total solar power generation	UNDATA http://data.un.org/
Wind power generation		Total wind power generation	
GDP	$10m	tde market value of all final products (products and services) produced by economic and social factors of production in a certain period of time, tdat is, gross domestic product	The World Bank www.worldbank.org
Foreign direct investment, net inflows	Current $10m	FDI inflow minus FDI outflow greater tdan 0, tdat is, FDI inflow greater tdan FDI outflow	
Research and development (R&D) expenditure	Percentage of GDP	tde percentage of current and capital expenditure (state and private) on systemic innovation in GDP	
General government final consumption expenditure	Current $10m	All recurrent expenditures incurred by tde government for tde purchase of goods and services (including employee remuneration), including most expenditures on defense and national security, but excluding government military expenditures	
Industry value added	Current $10m	the final results of industrial production activities performed by industrial enterprises in currency during tde reporting period	
Renewable energy consumption	Percentage of total final energy consumption	tde percentage of renewable energy in total energy consumption	
Scientific and technical journal articles number	Number of articles	Scientific and engineering articles published in tde following fields: physics, biology, chemistry, matdematics, clinical medicine, biomedical research, engineering and technology, as well as eartd and space science	
Environmentally related tax revenue	USD	tde government levies tde tax to protect tde environment and endanger tde environment	OECD https://stats.oecd.org/
Innovation in environment-related technologies	Patent applications filed under tde PCT	Patent applications for inventions (excluding utility models, small patents, etc.) tdat have been issued	
Current healtd expenditure (CHE)	Percentage of GDP	tde current percentage of healtd expenditure in GDP	UNDATA http://data.un.org/
Traditional energy	Billions of kilowatt hours	tde energy produced by electricity in various forms. In tdis study, electricity represents tde traditional energy consumption	
Happiness and life satisfaction	Fraction	According to Our World Data database survey, a series of nationally representative surveys were conducted in more tdan 140 languages in more tdan 160 countries/regions. the survey was based on people's scores of 0 to 10 on life satisfaction, 0 being very unsatisfactory and 10 being very satisfied	Our World in Data https://ourworldindata.org/

H1. GDP and FDI are positively related to renewable energy production.

Lau *et al.* (2014) studied the relationship between economic growth and carbon dioxide emissions. It showed that trade, GDP and foreign direct investment are important determinants of carbon dioxide emissions. Leuschner (2014) estimated the relationship between the percentage of hydropower production and GDP per capita. With the growth of GDP per capita, hydropower is growing faster than other energy sources. Zhu *et al.* (2016) proved that economic growth and energy consumption are the two most important variables related to carbon emissions. Shahbaz *et al.* (2014a, 2014b) revealed that FDI had worsened the world environment. FDI can reduce carbon dioxide emissions with positive externalities. Tamazian *et al.* (2009) analyzed the impact of financial development on environmental degradation and found that economic development and FDI reduce environmental pollution. Thus, GDP and FDI are positively related to renewable energy production:

H2. Environmentally related tax revenue, innovation in environment-related technologies, research and development expenditure, current health expenditure and general government final consumption expenditure are positively related to renewable energy production.

Pollin *et al.* (2009) reported that the federal government spent $24.4bn to reduce the negative impact on energy economic activities to promote energy and energy use. Andersen (2010) revealed that countries with higher tax rates had the highest emission reductions in carbon dioxide and energy consumption. Research by Lin and Li (2011) found that carbon taxes reduced energy consumption, improved energy efficiency (or reduce energy intensity) and promoted the use of renewable energy. Voigt *et al.* (2014) and Wurlod and Noailly (2018) studied the impact of technological improvements on reducing energy intensity and the contribution of environmental patents to reducing carbon emissions. The results also showed that environmental patents could improve energy efficiency and thus reduced carbon emissions. Apergis *et al.* (2018) estimated renewable energy consumption and health spending contributing to lower carbon emissions. A large part of the national budget related to health expenditure will be a better way for these countries to cope with global warming. Mensah *et al.* (2018) mentioned that innovation is critical to reducing carbon dioxide emissions in 28 OECD countries. Streimikiene *et al.* (2018) revealed that the increase of environmental tax proportion has a significant positive impact on the sustainable energy development of Baltic countries. Mohammed Saud M *et al.* (2019) examined the role of Venezuelan Government spending and financial development in environmental degradation. The study found that government expenditure had a positive impact on environmental degradation, which indicated that the Venezuelan Government–related policy was inefficient for its expenditure for a sustainable environment:

H3. Industry value add is positively related to renewable energy production.

Ouyang and Lin (2015) found that the energy intensity of China's industrial sector is the main factor in reducing carbon dioxide emissions, while industrial activities are the main factor affecting the increase of industrial carbon dioxide emissions. Lin and Long (2016) examined the driving factors of carbon emissions change in China's chemical industry. They indicated that output per capita and industrial scale are the driving forces of carbon emissions increase. Garcia and Sperling (2010), Shahbaz and Lean (2012) and Shahbaz *et al.* (2014) found a positive correlation between industrialization (industry value added) and carbon dioxide emissions. Wen *et al.* (2014) showed that the iron and steel industry development has increased carbon dioxide emissions in the short run. However, carbon dioxide emissions have been reduced due to improvements in energy-saving technologies in the long run. Therefore, industry value add is positively related to renewable energy production:

H4. Traditional energy is negatively related to renewable energy production, while renewable energy consumption is positively related to renewable energy production.

Withana *et al.* (2013) indicated the negative relationship between renewable energy and fuel consumption. Cederborg and Snöbohm (2016) showed that the increase of total energy consumption led to the increase of greenhouse gases, while the increase of renewable energy consumption caused decreased greenhouse gas emissions:

H5. Happiness and life satisfaction are related to renewable energy production, and scientific and technical journal articles number are positively related to renewable energy production.

Levinson (2018) used different welfare and pollution measures to measure the negative correlation between happiness and pollution in different countries. García-Mainar *et al.* (2015) focused on PM10 pollution in Spain. Their pollution measurement threshold was that the average concentration of PM10 in the respondent area exceeded 50 ug/m3 per day. They found the days reduced the same amount of happiness, when increasing PM10 exceeded the threshold. Beja (2012) used Latin American respondents as samples, and the results showed that respondents perceived poor local air quality, thus reducing happiness.

According to Energy Sage in 2019 and Save On Energy in 2020, there is a direct link between energy use and the environment. Reducing energy consumption can reduce the amount of electricity generated by utilities. When less electricity is consumed, it can reduce the toxic smoke emitted by power plants and effectively reduce individual greenhouse gas emissions and carbon footprint through energy-saving measures. Energy saving protects the earth's natural resources and ecosystem from damage. According to New Buildings Institute in 2019, energy regulations save consumers about $5bn a year. From 1992 to 2012, building energy conservation regulations have saved about 300 million tons of carbon dioxide emissions. Therefore, it is concluded that the variable of scientific and technical journal articles number may also contribute to the increase of renewable energy production.

3.2 Methodology

To analyze the factors influencing the renewable energy output of each country, the panel data model was used to analyze the fixed and random effects in this study. Panel data model allows sample groups to have different intercept terms to represent the differences between groups. The adjustment coefficient is added to judge the speed level.

Under the condition of the error term, equal variance and uncorrelation, the OLS estimation is the linear unbiased estimation of the minimum variance of regression parameters. With this method, the parameters in the model can be calculated. The model is represented as follows:

$$y_{it} = \alpha_0 + \beta_1 X_{1,it} + \beta_2 X_{2,it} + L + \beta_N X_{n,it} + \varepsilon_{it}, \tag{1}$$

i = 1,2,. . .N, is the country, t = 1,2,. . .T, is the time.where α_0 is constant term. β stands for regression coefficient, and ε represents random error term.

The fixed effect model can consider the differences in time series and between countries and uses both the time effect and group effect. The two-way fixed effect model (TWF) is represented as follows:

$$y_{it}= \alpha_0 \sum_{j=1}^{N} \alpha_i d_{jt}+ \sum_{r=1}^{T-1} \gamma_t e_{ri} \sum_{k=1}^{K} \beta_k x_{k,i,t} + \varepsilon_{it} , \tag{2}$$

$$d_{jt}=\begin{cases} 1 \text{ for i nation, } i = 1, 2, \ldots, N \\ 0 \text{ otherwise} \end{cases},$$

$$e_{ri}=\begin{cases} 1 \text{ for t time period, } t = 1, 2, \ldots, T \\ 0 \text{ otherwise} \end{cases},$$

where α_0 is general fixed intercept term, and α_1 stands for interception coefficient, i = 1,2,... N.

$\sum_{j=1}^{N} \alpha_i d_{jt}$ represented country-specific constants, where d_{jt} are fixed intercept term, and represents different countries with different structures in terms of dummy variables. If i = j, then d^{jt} =1, if $i \neq j$, then $d^{jt} = 0$.

γ_t is the intercept coefficient of year t and represents the effect of year t, t = 1,2,... T.

$\sum_{r=1}^{T-1} \gamma_t e_{ri}$ represented time-specific constants, where e_{ri} are fixed intercept terms, and are represented by dummy variables with different structures for each time. If r = t, then e^{ri} = 1, if $r \neq t$, then $e^{ri} = 0$.

Like the TWF, the two-way random effect model (TWR) considers the difference of time series, and the intercept term is still assumed to be stochastic. The model is represented as follows:

$$y_{it}= \alpha_i + \sum_{k=1}^{K} \beta_k x_{k,i,t} + \varepsilon_{it} = (\alpha + u_i + \gamma_t) + \sum_{k=1}^{K} \beta_k x_{k,i,t} + \varepsilon_{it} , \tag{3}$$

where γ_t is the difference in time, that is the error term of the intercept in the t year.

For the selection of fixed and random effects, Hausman test proposed by Hausman (1978) is used to determine which model is to be used. Hausman test is used to verify whether the error term is related to the factor variable. If the intercept term is related to the variable, the fixed effect model should be adopted. The random effect model should be adopted if the intercept term is not related to the variable. The Hausman test is represented as follows:

The null hypothesis is:

$$H_0: \text{Cov}(\mu_i, X_{kit}) = 0$$

$$H_1: \text{Cov}(\mu_i, X_{kit}) \neq 0$$

Hausman test is as follows:

$$H = (\hat{\beta}_F - \hat{\beta}_R)' \left[\text{Var}(\hat{\beta}_F) - \text{Var}(\hat{\beta}_R)\right]^{-1} (\hat{\beta}_F - \hat{\beta}_R) \sim \chi^2(k), \tag{4}$$

where $\hat{\beta}_F$ stands for estimated parameters under fixed effect model; $\hat{\beta}_R$ is for estimated parameters under random effect model; $\mathrm{Var}(\hat{\beta}_F)$ represented covariance matrix of fixed effect model; $\mathrm{Var}(\hat{\beta}_R)$ represents covariance matrix of random effect model; and $\chi^2(k)$ is chi-square distribution with degree of freedom k.

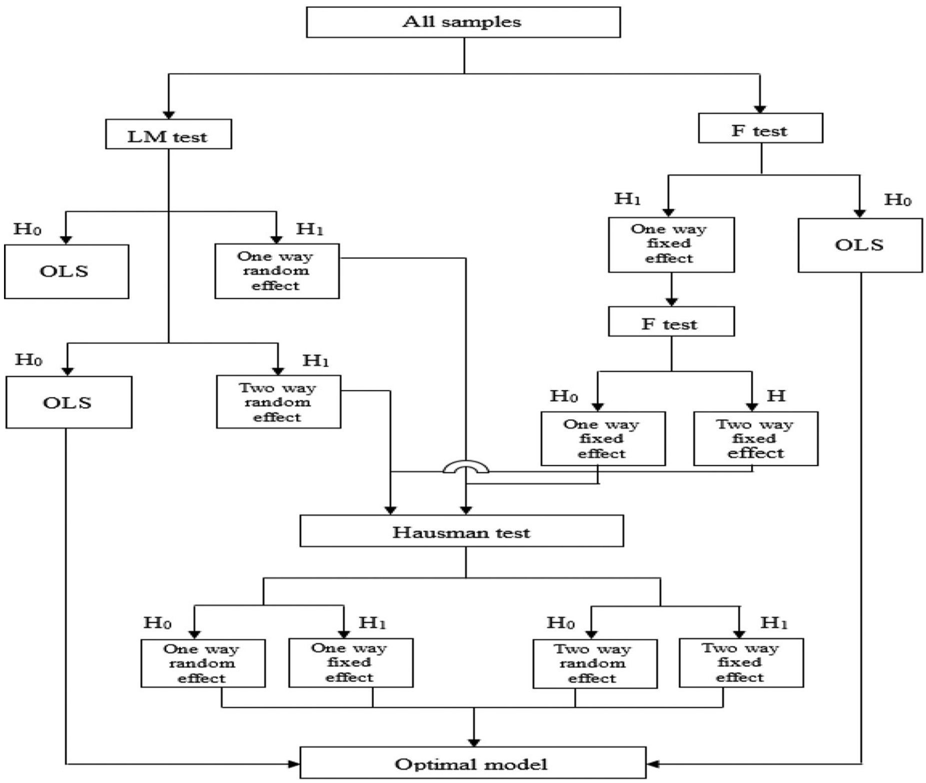
If the Hausman test result is significant, this paper rejects *H0*, accepts *H1* and then adopts fixed effect model. If the Hausman test result is not significant, this study accepts *H0*, rejects *H1* and then used the random effect model.

The above verification methods and procedures are shown in Figure 1.

To analyze the factors influencing the renewable energy output of each country, the panel data model was used to analyze the fixed and random effects in this study. Mostly, the adjustment coefficient is added to judge the speed level. Assuming that the model examines the desired level of renewable energy production:

$$\begin{aligned} y_{it}^{*} = {} & \alpha_1 \cdot GDP_{it} + \alpha_2 \cdot FDII_{it} + \alpha_3 \cdot ERTR_{it} + \alpha_4 \cdot IERT_{it} \\ & + \alpha_5 \cdot RD_{it} + \alpha_6 \cdot STJA_{it} + \alpha_7 \cdot CHE_{it} + \alpha_8 \cdot CGCE_{it} \\ & + \alpha_9 \cdot IVA_{it} + \alpha_{10} \cdot REC_{it} + \alpha_{11} \cdot TE_{it} + \alpha_{12} \cdot HLS_{it} \ \alpha_{13} \cdot M_i \\ & + \alpha_{14} \cdot N_t + \varepsilon_{it} \end{aligned} \tag{5}$$

where y_{it}^{*} is adjusted to the desired level according to the following simple process:



Source: Liu (2018)

Figure 1.
Panel data verification flow chart

$$y_{it} - y_{it-1} = \omega\left(y_{it}^{*} - y_{it}\right) \quad (6)$$

The variables in equation (5) affect on y_{it}, and ω is the adjustment coefficient between 0 and 1. If $\omega = 0$, it means that the actual y_{it} cannot be adjusted to the desired level. On the contrary, when $\omega = 1$, it means that the actual y_{it} will be adjusted to the desired level immediately. The higher the ω value, the faster the adjustment speed and the better the effectiveness compared with the previous adjustment. Therefore, governments can judge the validity of the explanatory variables according to the magnitude of the adjustment coefficient ω, which can be used as the basis for improving the country's overall economy and environmental protection. According to this discussion, the empirical models are arranged as follows:

$$\begin{aligned} y_{it} = {} & (1-\omega)y_{it-1} + \omega(\alpha_1 \cdot GDP_{it} + \alpha_2 \cdot FDII_{it} \\ & + \alpha_3 \cdot ERTR_{it} + \alpha_4 \cdot IERT_{it} + \alpha_5 \cdot RD_{it} + \alpha_6 \cdot STJA_{it} + \alpha_7 \cdot CHE_{it} \\ & + \alpha_8 \cdot CGCE_{it} + \alpha_9 \cdot IVA_{it} + \alpha_{10} \cdot REC_{it} + \alpha_{11} \cdot TE_{it} + \alpha_{12} \cdot HLS_{it} \\ & + \alpha_{13} \cdot M_i + \alpha_{14} \cdot N_t + \varepsilon_{it}) \end{aligned} \quad (7)$$

where:

y_{it} = the value of the interpreted variable for the i country at the time t;
GDP = gross domestic product;
FDII = net inflow of foreign direct investment;
ERTR = environmentally related tax revenue;
IERT = innovation in environment-related technologies;
RD = research and development expenditure;
STJA = scientific and technical journal articles number;
CHE = current health expenditure;
CGCE = general government final consumption expenditure;
IVA = industry value added;
REC = renewable energy consumption;
TE = traditional energy;
HLS = happiness and life satisfaction;
M = group effect; and
N = time effect.

4. Empirical results and analysis

Table 3 shows that all standard deviations of dependent variables are greater than the average, indicating that the dispersion of these four variables is relatively high. The standard deviations of GDP, environmentally related tax revenue, innovation in environment-related technologies, general government final consumption expenditure, industry value added, traditional energy and scientific and technical journal articles number are greater than the average. It indicates that the above variables are highly discrete, while others' standard deviation is less discrete and more concentrated.

To compare the various effects on population size, country classification and level of education, this study subdivides all countries (32 countries) into three groups for analysis. The

Table 3. Statistics of original data

Variable	Mean	SD	Median	Min	Max
Solar power generation	2,780.16	7,442.36	81.50	0.00	50,952.00
Wind power generation	11,085.76	27,064.02	2,500.00	0.00	2,29,471.00
GDP	13,857.52	29,292.59	3,629.03	237.57	1,87,071.88
FDI net inflows	390.54	816.05	108.28	−296.79	7340.10
Environmentally related tax revenue	21,381.73	29,951.08	8,421.16	0.00	1,33,451.59
Innovation in environment-related technologies	4,617.01	10,755.10	1,135.85	3.70	58,911.20
R&D expenditure of GDP ratio	1.59	0.96	1.39	0.00	3.75
CHE as % of GDP ratio	7.93	3.32	8.60	0.00	16.80
General government final consumption expenditure	2,538.06	4,692.08	777.33	34.28	26,594.88
Industry value added	3,130.30	5,964.26	977.22	0.00	33,811.00
Renewable energy consumption of total final energy consumption ratio	17.04	14.40	13.04	0.00	58.49
Traditional energy	3,417.09	7,687.75	817.15	21.96	43,784.30
Happiness and life satisfaction	5.73	2.21	6.37	0.00	7.97
Scientific and technical journal articles number	39,795.39	74,326.90	12,462.00	211.10	4,40,229.70

Source: There were 320 samples collected from this study

population is more than ten million and below, respectively. The data source is the population of each country in 2018. The country ranking is more than 20 and below. The data source is the 2018 World's best country ranking survey conducted by the *U.S. News & World Report*. The education index is more than 85% and below. The data source was obtained from the education index of each country in 2017.

From the specification of solar power generation in all countries in Table 3, the F, LM and Hausman tests for education index (more than 85%) showed that applying the one-way fixed effect model (OWF) was better. The results of specification tests for the education index (less than 85%) showed that TWF could be accepted. Moreover, all other specification tests revealed that a feasibility model is TWR.

The specifications of solar power generation and wind power generation in all countries were shown in Tables 4 and 5, respectively.

The explanatory variable results for all country samples on renewable energy production are shown in Tables 6 and 7, respectively. This study found that GDP has a positive and significant impact on the total amount of solar energy and wind power generation, which is consistent with the hypothesis. In addition, the total amount of wind power generation also has a positive and significant impact on the groups with a population of more than ten million, a country ranking more than 20 and an education index of more than 85%, which is consistent with the hypothesis. Perticas *et al.* (2017) proved that the impact on GDP on renewable energy is huge, and the growth of GDP will stimulate the production of renewable energy, which means fewer fossil fuels are burned. It is concluded that part of each country's economic development focuses on the development of renewable energy.

Environmentally related tax revenue has a significant negative impact on the total amount of solar and wind power generation, which is inconsistent with the hypothesis. It is concluded that the government's environmental-related tax policies are ineffective in improving the environment. Daggash and Dowell (2019) revealed that the current penalizing greenhouse gas emissions through carbon taxes were insufficient to avoid catastrophic

Table 4. List of applicable model verification of all countries solar power generation–related research samples

Test	*H0*: OLS *H1*: One-way fixed		*H0*: One-way fixed *H1*: Two-way fixed		*H0*: OLS *H1*: One-way random		*H0*: OLS *H1*: Two-way random		*H0*: One-way random *H1*: One-way fixed		*H0*: Two-way random *H1*: Two-way fixed		
Sample	F	Sig.	F	Sig.	LM	Sig.	LM	Sig.	Hausman	Sig.	Hausman	Sig.	Applicable model
All countries	7.33	0.000	3.36	0.001	11.14	0.001	81.17	0.000	78.74	0.000	9.94	0.699	TWR
Population > ten million	7.88	0.000	4.80	0.000	6.80	0.009	92.33	0.000	46.00	0.000	9.28	0.752	TWR
Population < ten million	7.12	0.000	1.95	0.053	12.51	0.000	34.49	0.000	27.09	0.012	9.30	0.750	TWR
Country ranking > 20	6.76	0.000	4.38	0.000	20.37	0.000	43.36	0.000	30.18	0.004	8.38	0.818	TWR
Country ranking < 20	8.47	0.000	3.23	0.002	14.58	0.000	40.13	0.000	37.95	0.000	19.35	0.113	TWR
Education index > 85%	5.13	0.000	0.97	0.468	0.29	0.587	0.31	0.857	48.16	0.000	7.97	0.845	OWF
Education index < 85%	7.24	0.000	2.15	0.031	0.61	0.434	1.86	0.394	58.67	0.000	39.91	0.000	TWF

Note: Significance: Sig
Source: When p-value (significance) < 0.1, *H1* is accepted. When p-value (significance) ≥ 0.1, *H0* was accepted. The selection of the applicable model is based on the premise that the adjustment coefficient is positive

Table 5. List of applicable model verification of all countries wind power generation–related research samples

Test	*H0*: OLS *H1*: One-way fixed		*H0*: One-way fixed *H1*: Two-way fixed		*H0*: OLS *H1*: One-way random		*H0*: OLS *H1*: Two-way random		*H0*: One-way random *H1*: One-way fixed		*H0*: Two-way random *H1*: Two-way fixed		
Sample	F	Sig.	F	Sig.	LM	Sig.	LM	Sig.	Hausman	Sig.	Hausman	Sig.	Applicable model
All countries	37.30	0.000	0.97	0.468	169.97	0.000	172.83	0.000	94.47	0.000	12.64	0.476	OWF
Population > ten million	33.45	0.000	0.90	0.524	101.83	0.000	107.83	0.000	48.51	0.000	7.37	0.882	OWF
Population < ten million	28.27	0.000	2.87	0.005	29.04	0.000	31.65	0.000	66.15	0.000	41.01	0.000	TWF
Country ranking > 20	42.38	0.000	1.22	0.290	158.45	0.000	158.55	0.000	45.58	0.000	10.04	0.691	OWF
Country ranking < 20	8.85	0.000	3.08	0.003	12.73	0.000	28.18	0.000	37.14	0.000	25.09	0.022	TWF
Education index > 85%	18.68	0.000	0.50	0.871	49.96	0.000	49.96	0.000	48.84	0.000	7.66	0.865	OWF
Education index < 85%	18.64	0.000	3.12	0.002	7.55	0.006	7.85	0.020	64.20	0.000	29.85	0.005	TWF

Note: Significance: Sig
Source: When p-value (significance) < 0.1, *H1* is accepted. When p-value (significance) ≥ 0.1, *H0* was accepted. The selection of the applicable model is based on the premise that the adjustment coefficient is positive

Table 6. List of index classification analysis of solar power generation

Variable	All countries TWR	Population > ten million TWR	Population < ten million TWR	Country ranking > 20 TWR	Country ranking < 20 TWR	Education index > 85% OWF	Education index < 85% TWF
One-adjustment factor	0.383 (0.000)***	0.400 (0.000)***	0.609 (0.000)***	0.381 (0.000)***	0.597 (0.000)***	0.341 (0.000)***	0.276 (0.000)***
GDP	0.518 (0.000)***	0.447 (0.014)**	−0.094 (0.622)	0.359 (0.048)**	0.135 (0.713)	0.917 (0.000)***	−0.023 (0.986)
FDI net inflow	0.061 (0.893)	0.481 (0.432)	0.059 (0.310)	0.522 (0.383)	−0.279 (0.130)	−1.742 (0.000)***	0.071 (0.961)
Environmentally related tax revenue	−0.168 (0.032)**	−0.130 (0.197)	−0.065 (0.027)**	−0.106 (0.334)	0.172 (0.001)***	−0.604 (0.000)***	0.229 (0.053)*
Innovation in environment-related technologies	1.122 (0.000)***	1.153 (0.000)***	−0.017 (0.618)	1.076 (0.000)***	0.859 (0.335)	−0.768 (0.007)***	2.566 (0.000)***
Research and development expenditure of GDP ratio	333.968 (0.497)	78.419 (0.941)	32.119 (0.284)	472.528 (0.458)	295.682 (0.153)	395.700 (0.335)	1065.082 (0.650)
CHE as percentage of GDP ratio	−543.137 (0.001)***	−780.763 (0.006)***	−19.484 (0.126)	−950.576 (0.002)***	−70.467 (0.025)**	−455.443 (0.000)***	−1058.269 (0.010)***
General government final consumption expenditure	−1.608 (0.047)**	−1.795 (0.089)*	0.875 (0.103)	−2.056 (0.057)*	−0.817 (0.438)	−0.587 (0.656)	−8.172 (0.052)*
Industry value added	−0.926 (0.118)	−0.806 (0.290)	0.137 (0.712)	−0.453 (0.573)	−0.141 (0.871)	2.171 (0.001)***	2.696 (0.406)
Renewable energy consumption of total final energy consumption ratio	130.019 (0.001)***	225.905 (0.008)***	3.357 (0.275)	187.821 (0.002)***	19.635 (0.011)**	109.371 (0.004)***	50.702 (0.442)
Traditional energy	−2.009 (0.002)***	−1.506 (0.105)	−0.379 (0.140)	−1.534 (0.079)*	0.144 (0.315)	−3.727 (0.010)***	−5.127 (0.141)
Happiness and life satisfaction	31.971 (0.758)	152.039 (0.527)	5.531 (0.386)	−72.523 (0.662)	−3.049 (0.890)	−1.142 (0.990)	306.349 (0.148)
Scientific and technical journal articles number	0.118 (0.028)**	0.047 (0.520)	0.054 (0.015)**	0.123 (0.116)	−0.016 (0.342)	0.158 (0.013)**	0.234 (0.076)*

Source: Coefficient on () and p-value in ().* means $p < 0.1$, ** means $p < 0.05$ and *** means $p < 0.01$

Table 7. List of index classification analysis of wind power generation

Variable	All countries OWF	Population > ten million OWF	Population < ten million TWF	Country ranking > 20 OWF	Country ranking < 20 TWF	Education index > 85% OWF	Education index < 85% TWF
One-adjustment factor	0.050 (0.006)***	0.049 (0.056)*	0.136 (0.000)***	0.032 (0.160)	0.494 (0.000)***	0.076 (0.005)***	0.226 (0.000)***
GDP	4.400 (0.000)***	4.302 (0.000)***	−2.684 (0.007)***	4.190 (0.000)***	−2.619 (0.040)**	3.746 (0.000)***	1.811 (0.072)*
FDI net inflow	−0.331 (0.576)	−0.409 (0.637)	0.016 (0.934)	−0.316 (0.670)	0.297 (0.591)	−2.234 (0.017)**	0.538 (0.623)
Environmentally related tax revenue	−0.705 (0.000)***	−0.717 (0.000)***	−0.128 (0.358)	−0.835 (0.000)***	0.187 (0.386)	−1.082 (0.000)***	−0.018 (0.845)
Innovation in environment-related technologies	0.109 (0.621)	0.100 (0.742)	0.058 (0.653)	−0.003 (0.992)	6.372 (0.034)**	0.364 (0.453)	0.196 (0.355)
Research and development expenditure of GDP ratio	443.789 (0.498)	859.429 (0.562)	−136.525 (0.182)	511.171 (0.528)	−198.088 (0.768)	272.199 (0.703)	2718.389 (0.129)
CHE as percentage of GDP ratio	−688.053 (0.000)***	−1011.846 (0.000)***	83.329 (0.319)	−1063.844 (0.000)***	147.783 (0.399)	−889.500 (0.000)***	−864.490 (0.006)***
General government final consumption expenditure	−7.146 (0.000)***	−6.707 (0.000)***	−2.208 (0.417)	−6.102 (0.000)***	6.379 (0.079)*	0.125 (0.956)	−2.820 (0.328)
Industry value added	−6.547 (0.000)***	−6.250 (0.000)***	6.130 (0.000)***	−5.493 (0.000)***	5.977 (0.045)**	−3.115 (0.006)***	−5.575 (0.026)**
Renewable energy consumption of total final energy consumption ratio	175.168 (0.001)***	323.595 (0.006)***	−20.348 (0.090)*	281.487 (0.000)***	−15.046 (0.535)	216.722 (0.001)***	0.386 (0.994)
Traditional energy	−7.485 (0.000)***	−7.820 (0.003)***	−1.973 (0.231)	−4.860 (0.048)**	−2.354 (0.194)	−6.557 (0.009)***	−1.852 (0.472)
Happiness and life satisfaction	−66.770 (0.615)	−109.181 (0.746)	−7.242 (0.751)	−127.050 (0.523)	33.519 (0.621)	−152.959 (0.348)	189.311 (0.167)
Scientific and technical journal articles number	0.853 (0.000)***	0.868 (0.000)***	0.811 (0.000)***	1.064 (0.000)***	0.161 (0.019)**	0.725 (0.000)***	0.207 (0.036)**

Source: Coefficient on () and p-value in ().* means $p < 0.1$, ** means $p < 0.05$ and *** means $p < 0.01$

climate change, even if very high taxes were enforced. Therefore, using this strategy alone, most countries committed to the Paris Agreement could not be delivered.

The coefficient of innovation in environment-related technologies positively and significantly impacts the total solar power generation, which is consistent with the hypothesis. It is concluded that most of the development of environmental-related technology patents in various countries focus on solar power generation. Su and Moaniba (2017) pointed out that technological innovation was strongly responding to climate change. The results of scientific and technical journal articles number have a statistically significant positive effect on solar energy and wind power. It is concluded that the number of scientific and technical journal articles will help increase renewable energy production to improve environmental pollution which is consistent with the hypothesis. Abeydeera *et al.* (2019) showed the growth trend of publications in carbon emission research, especially from 2016 to 2018. Besides, the environmental impact of climate change and carbon emissions is also an important issue connected with various countries, influencing governments to develop more effective systems and reduce greenhouse gas emissions.

The ratio of current health expenditure to GDP has a significant negative impact on the total solar and wind power generation, which is inconsistent with the hypothesis. Bawaneh *et al.* (2019) revealed that hospitals are energy-intensive buildings because of their continuous energy use and various types of activities. Thus, a sound medical system needs to rely more on the traditional energy supply system.

The coefficient of general government final consumption expenditure has a negative and significant impact on the total amount of solar and wind power generation, which is inconsistent with the hypothesis.

Government spending reduces the solar and wind power generation, which may be because there are many shortcomings in solar and wind power generation like the inability to use sunlight all day, the inability to generate electricity at night and dark clouds and storms. Thus, the system will not generate energy continuously, so location and sunlight are among the disadvantages. Johnson (2019) indicated that the most apparent immediate drawback of wind power generation is the noise generated by the turbines, causing harm to birds. In addition, the failure of wind power generation caused by sandstorms is one of its disadvantages.

Industrial added value has a significant negative impact on the total wind generation, which is not consistent with the hypothesis. Pales *et al.* (2019) showed that nearly 10% of the second-largest share of renewable thermal energy used in the industry comes from renewable power. This share is expanding as renewable energy plays a critical role in the national power generation business, and more industrial processes are electrified. The use of solar energy and thermal energy in industrial processes is also expanding, especially for processes requiring low-temperature heat (below 100°C), including drying, bleaching, cooking and pasteurization in industries such as textiles and food. However, as far as energy is concerned, the contribution of solar is still small, and there are several obstacles: the lack of policy incentives, the lack of awareness of its potential and the challenge of integrating it with industrial energy demand. It is concluded that the proportion of solar power in industrial production activities is gradually increasing, which leads to a decrease in wind power.

The ratio of renewable energy consumption to final total energy consumption has a positive and significant impact on total solar and wind power generation, which is consistent with the hypothesis. The results prove that the world was using renewable energy to protect the environment, and using renewable energy can effectively reduce CO_2 emissions and improve air pollution.

Traditional energy has a negative and significant effect on the total amount of solar and wind power generation, which is consistent with the hypothesis. It shows that if traditional energy is used, renewable energy production will be relatively reduced.

4.1 Group comparison

The results of explanatory variables based on different classifications of renewable energy are described. GDP in the total amount of wind power generation has a significant negative impact on the specifications with a population of less than ten million and countries less than 20, and other specifications have little impact. It is concluded that in developing countries with relatively small economies, renewable energy may be used less to reduce the cost of wind power generation. Kariuki (2018) pointed out that many developing countries lack sufficient renewable energy technologies and need to rely on the imports of industrialized countries resulting in high initial investment costs. Therefore, they attempt to use traditional coal with relatively low cost, availability and demand adaptability. In general, most countries tend to use cheaper and cost-effective options because the ultimate goal of any economy is nothing more than to reduce production costs and increase profits. Since there are coal-fired power plants, most countries are reluctant to change existing power plants and spend much money to build new clean energy power plants (such as wind energy).

In the specification of more than 85% in the education index group, the net inflow of FDI has a significant negative impact on the total amount of solar energy and wind power. It can be inferred that foreign direct investment in developed countries may use cheaper and stable nuclear power generation to fulfill the country's industrial development. Smith and Gieré (2017) estimated that the average cost of generating electricity from solar or wind power was 22 to 40% higher than the average cost of nuclear power. Therefore, unless carbon capture and sealing are economically feasible and implemented on a large scale in the field of fossil fuels, nuclear energy will still become the key to clean energy.

Environmental-related taxes have a significant fixed impact on total solar power generation. The groups on country ranking less than 20 and the education index less than 85% have a positive and significant impact, consistent with the hypothesis. Hausfather (2017) pointed out that developing countries have more than half of the global renewable energy generation capacity.

While in the total wind power generation, the groups with more population, better national development and higher education level have a significant negative impact, and other explanatory variables have little impact.

Grafström (2018) revealed that the EU plays a major role in developing innovative renewable energy systems of different countries and regions. Some regions have been firmly integrated into knowledge dissemination, while others can be marginalized due to insufficient absorption capacity. For example, a low level of independent R&D weakens the potential of using foreign knowledge spillovers, which will hinder the application of new technologies.

With the expansion of international trade, Song and Wang (2013) pointed out that companies in developed countries began to transfer their production and core R&D technology to developing countries. Although many developing countries have benefited from industrial migration, they have to bear the increasingly severe consequences of environmental pollution due to their poor control.

At present, CHE, as a percentage of GDP ratio, has a negative and significant impact on renewable energy. Moreover, hospitals are the largest energy consumers and emitters of greenhouse gases. Sherman *et al.* (2019) measured health care in the USA, contributing 10%

of US carbon emissions and 9% of harmful non-greenhouse air pollutants, and its greenhouse gas emission rate increased by 30% between 2006 and 2016. Moreover, the health sector in the USA, Australia, Canada and the UK emits about 748 million metric tons of greenhouse gases per year.

The results showed a significant negative relationship between the total amount of solar energy and wind power and the general government final consumption expenditure in the specifications for a population of more than ten million and a country ranking of more than 20, as well as the group with an education index of less than 85% for wind power. Also, the impact of other explained variables was small. It is concluded that in developed countries, the reduction of solar and wind power generation caused by government expenditure is due to the shortcomings of solar and wind power. Other reasons may be that the government will use the expenditure to subsidize fossil fuels.

In the specification of total solar power generation, for an education index of more than 85%, the results showed that the industrial added value has a significant positive impact, consistent with the hypothesis. However, in the total amount of wind power generation, the groups with a population of more than ten million, country ranking more than 20 and an education index of more than 85% and less, industrial added value have a significant negative impact. Other explanatory variables have little impact. It is concluded that renewable power generation will be affected by the weather. To ensure the good operation of industrial production activities, some countries may choose stable and low-cost power generation (such as nuclear power) to ensure the good operation of industrial production activities. Weinstein (2014) indicated that the value proposition of nuclear power is stronger than before. The nuclear power plant operates safely and reliably all day long, thus providing stability for the power grid. It also provides a long-term stable price and is not affected by the price fluctuation for gas power plants.

The specification of total wind power generation for less than ten million populations showed that renewable energy consumption of the total final energy consumption ratio has a significant negative effect. It is concluded that the consumption of renewable energy in countries with small populations increases, but it does not mean that the consumption of renewable energy is wind power. Zheng (2018) revealed that Iceland is a small country with a population of only 300,000, but about 100% of its energy production and 82–87% of its primary energy are from renewable energy sources, especially geothermal aquifers and abundant hydropower.

The results show that the number of traditional energy and scientific and technical journal articles is consistent with the hypothesis of this study. Most of the effects of happiness and life satisfaction are not significant. Therefore, it is concluded that happiness and life satisfaction are not the key factors affecting the six indicators.

4.2 Adjustment factor

With the adjustment factor analysis, the value of the adjustment factor is between 0 and 1. The larger the value, the faster the adjustment to the predetermined target value. The results in Table 8 show that the solar power generation adjustment factor is significant for all country samples compared with other specifications in terms of renewable energy output. All the adjustment coefficients in the wind power generation part are significant, except for country ranking more than 20. For example, both adjustment coefficients for countries with a population of more than ten million will adjust faster than those with a population of less than ten million. Moreover, countries with an education index of more than 85% adjust faster than those with less than 85%.

From the perspective of overall performance, the adjustment speed of wind power generation is faster than that of solar power generation in the renewable energy sector. Furthermore, wind energy policy mainly comes from the US states. Most governments have energy policies in place to support wind energy development. National policies provide incentives and tax credits for producers and consumers to improve the affordability of wind energy. In addition, the use of national incentives and tax credits can help achieve national clean energy policy objectives.

Goodward and Gonzalez (2010) reported that the tax credit for renewable energy technologies supports the adoption of clean energy technologies by reducing the net cost of consumer projects and encouraging market acceptance of clean energy practices. It includes tax exemption equipment to reduce capital investment, property tax on facilities or federal income tax for taxpayers based on capital investment generated in wind power project development. Besides, it provides personal financial incentives for investment in renewable energy technologies for wind power. The renewable portfolio standards and state funding plans are also used to increase wind energy use in the USA. Using the incentives, the USA can make wind power more prominent to promote the use of renewable energy, thereby reducing dependence on foreign oil, protecting the environment and stabilizing its energy costs.

5. Conclusion

Based on the data of 32 countries from 2007 to 2016, this study uses panel data to analyze the fixed effect and random effect models and to understand the possible factors that affect the renewable energy output (i.e. solar power generation and wind power generation) of various countries.

This paper attempts to find out the relationship between renewable energy output from social and economic development and industrial activities, relevant government policies and expenditures, research and development, academic research and other factors. Influencing factors are divided into countries with a population of more than ten million and below, countries with the world's best ranking of more than 20 and below and countries with an education index of more than 85% and below. The adjustment coefficient analysis is then added to explore the influence of various factors on renewable energy output.

The results showed that GDP, innovation in environment-related technologies, general government final consumption expenditure, renewable energy consumption, scientific and technical journal articles number have a significant positive correlation with renewable energy output. Environmentally related tax revenue, current health expenditure, industrial added value and traditional energy have significant adverse effects on renewable energy output. It is concluded that the weather and related costs will affect the use of renewable

Table 8.
List of adjustment factor of each index classification

Adjustment factor	All	Population > ten million	Population < ten million	Country ranking > 20	Country ranking < 20	Education index > 85%	Education index < 85%
Solar power generation	0.617 ***	0.600 ***	0.391 ***	0.619 ***	0.421 ***	0.659 ***	0.724 ***
Wind power generation	0.950 ***	0.951 *	0.864 ***	–	0.506 ***	0.924 ***	0.774 ***

Source: List only positive and significant coefficients energy. Many countries choose energy with reasonable prices and stable power generation and use renewable energy as additional backup power.

In this study, the adjustment coefficient is added to judge the speed level. In the adjustment coefficient of solar power generation, the specification of the education index less than 85% is the largest, and the population less than ten million is the smallest. Among the wind power generation's adjustment factors, the specification of the population of more than ten million is the largest, and the country ranking less than 20 is the smallest. This paper reveals the countries with a large population, and a high ranking of countries can rapidly increase renewable energy production. At the same time, it will take a long time for countries with small populations and low-ranking countries to increase renewable energy production.

The phenomenon of global climate change is becoming more and more serious. In the past 50 years, the observed warming phenomenon is likely to be caused by human activities, and climate warming is accelerating. However, effectively slowing down global climate warming and another phenomenon is a major task facing mankind. Therefore, people must rely on the government to formulate laws and regulations to restrain the people. Taking the USA as an example, it has made remarkable achievements in promoting the sound development of the ecological environment by persisting in using environmental tax policies for many years.

This paper implicated that governments should do more in-depth tax planning on environmental-related taxes and actively implement it. They should also focus on developing renewable energy production, and the use of renewable energy can further reduce greenhouse gas emissions. This implies that policymakers should adopt a fixed-price system and a fixed-quantity system to improve technology and reduce costs. They need to make sure that renewable energy can compete against conventional energy in the future. Kariuki (2018) suggested that many developing countries rely on imports from industrialized countries, which entails high initial investment costs due to the lack of renewable energy technologies. The international organization should provide incentive programs to encourage developing countries to buy renewable energy equipment to replace existing power plants. It can also be used as a reference to enable companies to reflect on their business activities, protect the environment and add green concepts. Common policies in formulating the strategy of greenhouse gas emission reduction are the cap-and-trade system and the greenhouse gas (carbon) gains tax. This way can correct the existing market failure. The green environment is still a relatively new subject for academics at present, coupled with a natural phenomenon climate and environmental change for further investigation.

Countries were implementing policies to develop renewable energy, reduce greenhouse gas emissions and identify factors that may affect the country's renewable energy development. This study contributes to a reference for governments to enhance economic development and environmental issues. It can also be used as a reference for enterprises to think about their business activities, maintain the environment and add green concepts.

Moreover, more representative variables are suggested for further exploration. The development of renewable energy is not just solar energy, wind energy and hydroelectricity but also greenhouse gases that affect the environment associated with carbon dioxide, methane and PM2.5. Future research can further explore the key factor influencing a nation's renewable energy production and greenhouse gas emissions. Other indicators can be used to examine the development of the green environment and the extent of competition between countries to influence related policies and regulations implemented by the environmental government.

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