Renewable Energy Contribution to Economic Growth in OECD countries

Yenilenebilir Enerjinin OECD Ülkelerinde Ekonomik Büyümeye Katkısı

Ramandray FELIX[1]

Abstract

In the scope of climate change mitigation, renewable energy deployment has been given a priority in the energy policy of many countries in order to reduce the dependence on non-renewable energy. A significant drop in the price of renewable energy technology has been observed over decades, which led to an increase in the share of renewable energy in the energy production. Then, the present study investigates the renewable energy contribution to economic growth in OECD countries over the period between 1996 and 2014 in the context of panel data model. The results support that the growth in renewable energy use has a significant and positive impact on economic growth. Therefore, policymaker should continue to support renewable energy-based power plant installation.

Keywords: Renewable and non-renewable energy, Economic growth, Panel data model

Öz

İklim değişikliğinin azaltılması kapsamında yenilenemez olan enerjiye bağımlılığı azaltmak amacıyla birçok ülkenin enerji politikasında yenilenebilir enerji kullanımına öncelik verilmiştir. Yıllar boyunca yenilenebilir enerji teknolojisinin fiyatında, enerji üretiminde yenilenebilir enerji payının artmasına yol açan önemli bir düşüş gözlenmiştir. Bu çalışma, OECD ülkeleri için 1996 ve 2014 arasındaki panel veri modelleri bağlamında yenilenebilir enerjinin etkisini incelemekte. Sonuç, yenilenebilir enerji kullanımındaki artışın ekonomik büyüme üzerine anlamlı ve pozitif bir etki olduğunu göstermektedir. Bu nedenle, politika yapıcı, yenilenebilir enerji santralinin kurulumunu desteklemeye devam etmelidir.

Anahtar Sözcükler: Yenilenebilir ve yenilenemez enerji, ekonomik büyüme, panel veri modelleri

1. INTRODUCTION

Substituting non-renewable source-based energy with renewable one lies in the policy strategy to mitigate the climate change issue. The debate on this subject has attracted many researchers who affirmed that climate change started to inflict serious damage to the ecosystem. One way to address this issue is to decrease the dependence on non-renewable energy source as it expands green gas emission and creates negative externalities on natural resource quality and human life (Vouvaki and Xepapades, 2008; Empora and Mamuneas, 2011), that is, shifting to the utilization of renewable energy since this type of energy source is environment-friendly (Ito, 2017; Chen and al. 2018; Lin and Moubarak, 2014).

Energy policy aims to decrease green gas emission by promoting renewable energy use through various means such as feed-in-tariffs, renewable energy certificate, and credit and tax benefits…etc. Over the last decades, the cost associated with renewable energy has seen a significant fall thanks to the technological progress, and this has contributed to the growth of the use of renewables (Bowden and al., 2009). In addition to this, the fluctuation in the oil price has been also a significant factor (Apergis and Payne, 2010). As a result, many countries have shown a significant increase in renewable energy deployment. For instance, European Union installed almost 12.5 GW renewable energy capacity in 2016, which brings the cumulative capacity to 153.7 GW. Germany installed almost 5 GW wind capacity and doubled wind power capacity between 2009 and 2006 (REN21, 2018). This high completion is in part due to the shift from guaranteed fit to the competitive auctions. China deployed 23.4

[1] **Ramandray FELIX**
ORCID ID: 0000-0003-0688-1956
Doktor Adayı, Ege Üniversitesi, İktisat Bölümü, İstanbul, İzmir, TÜRKİYE, ramandrayf@gmail.com
PhD Candidate, Ege University, Economics Department, Izmir, TURKEY, ramandrayf@gmail.com

Geliş Tarihi/*Received* : 26.11.2019
Kabul Tarihi/*Accepted* : 20.01.2020
Çevrimiçi Yayın/*Published* : 20.01.2020

Makale Atıf Önerisi /Citation (APA):
Felix, R. (2019). Renewable Energy Contribution to Economic Growth in OECD countries. *İzmir Sosyal Bilimler Dergisi*, 1 (2), 86-93.

GW of wind power capacity in 2016 making its total installed capacity to 169 GW which constitutes one-third of global capacity by the end of 2016. Feed-in-tariff policy applied the Chinese government has contributed to this great performance.

A number of papers in the literature have addressed the contribution of renewable energy to economic growth by using different methodologies. There are four types of relationship between energy use and economic growth (Apergis and Tang, 2012). First, the growth hypothesis means that there is one direction of causality from energy use to economic growth that is, energy consumption support output growth but the latter does not influence energy consumption. Second, the neutrality hypothesis suggests the absence of a link between economic growth and energy use i.e. any change in energy consumption does not alter economic growth and vice versa. Third, the feedback hypothesis states that there is a double direction in the relationship between economic growth and energy use, that is, both simultaneously influence each other. The fourth, the conservation hypothesis indicates that economic growth promotes the expansion of renewable energy use but the latter does not have any influence on the former.

The Granger causality test is among the widespread methodologies used by many authors, such as (Tugcu and Tiwari, 2016; Soytas and Sari, 2006; Apergis and Payne, 2012; Tang and al., 2016), to find the effect of renewable energy on any variables. This test allows determining as to whether there is bidirectional causality between renewable energy and economic growth. Gozgor and al. (2018), Alvare-Herranz and al. (2017), Inglesi-Lotz (2015), Salim and al. (2014), Apergis and Payne (2010), among others, investigated the effect of renewable energy on economic growth in OECD countries and affirmed the positive contribution. The same study has been carried out in G7 countries by Soytas and Sari, 2006), in BRICS by Tugcu and Tiwari (2016), in China by Lin and al. (2014), in Turkey by Dogan (2016) and in Vietnam by Tang and al. (2016). Others studied the linkage between renewable and non-renewable energy and greenhouse emission (Ito, 2017; Chen and al., 2018; Lin and Moubarak, 2014; Long and al., 2015).

Most of the works in the literature dealt with non-input variables like inflation, trade, etc., and used first levelled variable in order to study the effect of renewable energy on the economy. Moreover, most of their model applied Granger causality. Such model does not take into account the issue associated with country's specific effect. Therefore, with panel data analysis, this present paper investigates the contribution of renewable energy to economic growth in 21 OECD countries between 1996 and 2014 with regard to the traditional growth theory (e.g.: Solow model (Solow, 1956), that is, all variables are production factors like capital, labour and technology and expressed in terms of growth rate. Besides the commonly used production inputs (the growth of capital stock and labour), the growth in the research and development is included in the model as a proxy for the technological progress since it has become a central growth-accounting factor introduced by Romer (1990). Furthermore, the growth in non-renewable energy use is also added in order to avoid a biased result from the variable omission although the aim is to find the effect of renewable energy. After applying panel data model, the result of this paper revealed that the growth of renewable energy use, as well as the remaining four factors, has a significant positive effect on economic growth. The rest of this paper is organized as the following: Section 2 shortly discusses the literature review. The econometric model and data are introduced in section 3 and the result of empirical findings is reported in section 4. Finally, the conclusion takes place in section 5.

2. LITERATURE REVIEW

Many authors analysed the linkage between renewable energy and economic growth via panel data within an existing organisation like OECD, BRICS, etc. OECD countries are classified as a country group having the ability to produce the highest complex goods which are thought to essentially drive their economy. Such ability involves advanced industry and then a high level of energy consumption. Gozgor and al. (2018) studied the impact of renewable and non-renewable energy use on economic complexity indicator and economic growth in OECD countries covering the data between 1990 and 2013 by employing the panel autoregressive distributed lag (ARDL) and argued that economic growth and economic complexity are positively influenced by these energy types. Salim and al. (2014) investigated the dynamic linkage between renewable and non-renewable energy use and industrial output and economic growth with panel cointegration technique allowing the structural breaks and data in OECD countries over the period between 1980 and 2011, and proved that there is bidirectional causality between industrial output and both renewable and non-renewable energy uses in the short and long period, and there is only a short-run double causality between non-renewable energy and economic growth. Apergis and Payne (2010) analysed the nexus between renewable energy and economic growth with panel error correction model and panel cointegration, and data of twenty OECD countries covering the period between 1985 and 2005, and pointed out that there is bidirectional causality between renewable energy use and output growth in the short and long-term. Tugcu and Tiwari (2016) examined the causal linkage between energy consumption and total factor productivity (TFP) in Brazil, Russia, India, China, and South-Africa using the panel bootstrap Granger causality test and covering the period between 1992 and 2012, and find no relationship between renewable energy consumption and TFP growth.

Some authors study this relationship in a specific group of countries. Soytas and Sari (2006) investigated the link between real GDP and energy consumption in G-7 countries as well as in some emerging countries over the period between 1950 and 1992 using Granger causality. Their result has shown a conservative hypothesis in Italy and Korea, a feedback hypothesis in Argentina and a growth hypothesis in Germany, France, Japan, and Turkey. Considering the ordinary least-square (OLS), fully-modified ordinary least square (FMOLS) and the dynamic ordinary least square (DOLS) estimators, Jebli and Youssef (2015) asserted that there is growth hypothesis in the direction running from renewable and non-renewable energy use to the economic growth in 69 countries over the periods between 1980 and 2010.

Apergis and Payne (2012) demonstrated a double direction causality in the linkage between renewable energy and output growth for a dataset including 80 countries and covering the period between 1990 and 2007 by using the panel error correction model (ECM).

Others focused on a single country. Dogan (2016) explored the short and long-run relationship between energy consumption and economic growth in Turkey using structural break estimation in which energy use is separated with respect to their source, such as renewable and non-renewable, as well as their effect on the economy. The author argued that renewable energy influences Turkish economy positively but insignificantly, whereas that of non-renewable energy is positive and significant. Tang and al. (2016) investigated the effect of energy conservation policy on economic growth in Vietnam, that is, the linkage between energy use and Vietnamese economic growth covering the period between 1971 and 2011 by using Granger causality, and find that there exists one direction in the causality running from energy use to economic growth. In their work, they included other variables, capital stock and foreign direct indirect, which may affect economic growth in order to avoid variable omission. Lin and al. (2014) investigated the linkage between renewable energy consumption and Chinese GDP growth for the period between 1977 and 2011 by using Autoregressive distributed lag approach (ARDL) and indicated that there is bidirectional long-term causality between renewable energy and output growth. The present study aims at investigating the contribution of renewable energy in OECD countries' economic growth via a static panel data model.

3. DATA, EMPIRICAL MODEL AND METHODOLOGY

This present paper investigates the empirical effect of renewable energy on the economic growth in OECD countries.

3.1. Data and Empirical model

Some works in the literature ignored the research and development in their model although it is considered as an essential determinant factor of technology. In the Romer model (Romer, 1990), economic growth is driven by technology which is supported by the research and development. Then, let assume a Cobb-Douglass production function with five inputs such as labour (L), capital (K), research and development (A) and renewable (X_1) and non-renewable (X_2) energy use.

$$Y = F(A(t), K(t), X1(t), X2(t), L(t)) = A^{\rho}(t)K^{\alpha}(t)X_1^{\gamma}(t)X_2^{\theta}(t)L^{\beta}(t)$$

Where ρ, α, γ, θ and β denote the share of research and development, capital stock, renewable energy, non-renewable energy and labor in the production, respectively. It is worth saying that research and development is a proxy for the technology. By taking the time-derivative of the above function logarithmically, one obtains:

$$g_Y = \rho g_A + \alpha g_k + \gamma g_{x1} + \theta g_{x2} + \beta n$$

In the mainstream growth theory, capital, labour, and research, and development are expected to have a positive contribution to economic growth. Then, all these variables are expected to have a positive coefficient in the estimation result, that is, they have a positive effect on output growth. In this present paper, the following model for the empirical study is used:

$$GDPg = \alpha Kg + \gamma RENg + \theta NRENg + \beta LABg$$

where GDPg is the growth rate of gross domestic product in constant 2011 Us dollar; Kg is the growth of gross fixed capital formation stock in constant 2011 Us dollar; RENg is the growth of renewable energy use; NRENg is the growth of non-renewable energy use and LABg is the population growth. Gross fixed capital formation is used as a proxy for capital; labour force for the population taking part in the production; the spending on research and development is a proxy for technology. Renewable energy describes the primary energy yielded from geothermal wind, hydro, tide, wave sources and solar, whereas non-renewable energy is calculated by taking the difference between primary energy supply and renewable energy use.

Primary energy supply is referred to as the energy production added with imported energy and stock change (positive or negative) and with the subtraction of energy export and international bunker. This study uses panel data with time periods between 1996 and 2014 and covers the following countries: Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Germany Greece, Hungary, Iceland, Ireland, Italy, Korea, Luxembourg, Mexico, Netherland, New Zealand Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and Turkey. The selections of these countries and the time-period are based on data availability. The aggregate dataset for gross fixed capital formation, labour force, research and development and renewable and non-renewable energy use is taken from the OECD website.

Our dataset shows that gross domestic product growth ranges from -9.13% to 11.3% and the mean is equal to 2.37%. This lowest level indicates that some countries have very poor economic growth performance. In 2011, Greece exhibited -9.13% in 2011 following the economic crisis that heavily damaged its economy, and this negative growth was associated with an unprecedented fall in investment, around -20% in the same year. The crisis was also reflected in the country's consumption of non-renewable energy and its performance in renewable power plant deployment. Non-renewable energy consumption has decreased by 3.49%, whereas that of renewable energy has increased by 0.39%. Thus, there has been a drop in total energy consumption. A summary of descriptive statistics is reported in Table 1.

Table 1: Summary of descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GDPg	494	2.377656	2.912712	-9.13249	11.3086
Kg	494	2.7436	8.133781	-47.7609	31.9654
RENg	494	5.13791	9.551706	-69.30729	51.3235
NRENg	494	.3042858	5.527204	-28.09233	32.60877
LABg	494	.9308394	1.260226	-3.55086	5.39034

4. METHODOLOGY

The methodology in this paper deals with panel data model which consists of cross-sectional observation overtimes. Following Greene (2012), the basic framework for the panel data model takes the following form:

$y_{it} = x'_{it}\beta + z'_{it}\alpha + \varepsilon_{it}$ (1) for $i = 1, 2, \ldots n;\ t = 1, 2, \ldots, T$

where y_{it}: dependent variable; i: cross-sectional dimension; t: time dimension; x_{it}: k*1 vector of explanatory variables; z_i: the individual effect; α: constant term.

Panel data model deals with heterogeneity issue across individuals by including specific component which is either fixed or random. In general, panel data analysis has three approaches: pooled panels, fixed-effects and random-effects models, and the selection between these models is based on the relevant specification test known as the Hausman test and Breusch-Pagan test. The feature of z_{it} is very important in the analysis since it determines which model can be applied. If the control variables can capture all pertinent features of individual effects, there would be no critical unobserved characteristics. Thus, pooled data regression (OLS) would be appropriate to fit the model, which considers all observations as a single sample. It is not however known that the control variables capture it; then, it is impossible to directly perform a pooled data regression. If such regression is done without having any information on whether there are relevant unobserved effects, the estimated result would be biased due to omitted variables. In that case, fixed-effects (FE) or random effects (RE) would be preferable. In fixed-effect model, the specific effects associated with the country are assumed to be a fixed parameter, that is, it does not change across countries, whereas it is regarded as stochastic in the random-effects model.

4.1. Pooled regression

In this model, z_i is assumed to be an observed variable for all individuals. The least-squares estimator can deal with the model and give an efficient and consistent result. The pooled model uses ordinary least squares and has the following form:

$$y_{it} = x'_{it}\beta + \alpha + \varepsilon_{it} \quad (2)$$

where x_i are independent and exogenous; $i = 1 \ldots \ldots n$. Here it is assumed that the heterogeneity remains the same across individuals. A pooled model is applied under the assumption that there is no heteroscedasticity and autocorrelation. OLS estimator is BLUE in that case and then is used to estimate the model. These assumptions are:

Expected value equals zero:

$$E(\varepsilon_{it}) = 0$$

No perfect collinearity:

$rank(X) = rank(X'X) = n$ where X is a matrix (k, n) and X' is the transpose of X.

Exogeneity

$$E(\varepsilon_{it}/X) = 0; Cov(\varepsilon_{it}, X) = 0$$

Homoscedasticity:

$$Var(\varepsilon_{it}/X) = \sigma^2$$

No correlation in time series or cross section:

$$Cov(\varepsilon_{it}, \varepsilon_{jt}/X) = 0; i \neq j$$

Normal distribution of disturbances ε_{it}

In case there is cross-section dependence, the ordinary least square estimator would be inconsistent since it would bring about a high biased estimate of standard errors and then, t-statistics.

4.2. Random-effects model

Unlike the pooled-model, it takes into account individual-specific content which can lead to biased results in the case of OLS. In this model, the individual effect is uncorrelated with the regressors and the model is expressed as the following:

$$y_{it} = x'_{it}\beta + (\gamma + \mu_i) + \varepsilon_{it} \quad (3)$$

where p_i denotes a group-specific random element or a constant random heterogeneity associated with i-th observation and γ the mean of unobserved heterogeneity. The presence of p_i can induce inefficient least-square result. Random-effect model has the following assumptions:

Zero expected value:

$$E(\varepsilon_{it}) = 0$$

Exogeneity:

$$E(\mu_i|X) = 0; Cov(\mu_i, x_i) = 0$$

Homoscedasticity:

$$Var(\varepsilon_{it}|X) = \sigma_\varepsilon^2;\ Var(\mu_i|X) = \sigma_\mu^2$$

Normal distribution of disturbances ε_{it}

4.3. Fixed-effect model

In this model, z_i is unobserved and correlated with the regressors and then, it induces biased result in the OLS estimator as an omitting variable effect. It is given by the following formula:

$$y_{it} = x'_{it}\beta + \mu_i + \varepsilon_{it} \quad (4)$$

The conditional mean and variance between μ_i and x_i associate with one individual are assumed to remain constant (or fixe) for all periods. These are the assumptions for the fixed-effect model:

Zero expected value

$$E(\varepsilon_{it}) = 0$$

Exogeneity

$$E(\varepsilon_{it}|X, \mu_i) = 0; Cov(\varepsilon_{it}, X) = 0$$

Homoscedasticity:

$$Var(\varepsilon_{it}|X, \mu_i) = \sigma^2$$

Normal distribution of disturbances ε_{it}

4.4. Model selection

Hausman specification test

It is used to assess the consistency of an estimator versus another less efficient but assumed to be consistent, and help to select which one best fits the observations. This test can be applied to decide whether fixed-effects or random-effects should be selected for the panel dataset. Under the null hypothesis, the random-effect estimator is assumed to be consistent and efficient but fixed-effect to be inefficient. It is represented by the following forms:

$$H = (B_1 - B_0)'[var(B_0) - var(B_1)]'(B_1 - B_0) \sim \mathcal{X}_k^2 \qquad (5)$$

where ı indicates matrix inverse and k is a degree of freedom equal to the rank of matrix $var(B_0) - var(B_1)$under the null hypothesis. B0 and B1 are fixed-effect and random-effect estimators, respectively. In case the null hypothesis is accepted, the random-effect model best fits the observations. Otherwise, the fixed-effect estimator would be selected.

Breusch-Pagan test

This test is used to select between pooled-model and random-effects model in panel data analysis and is expressed in the following form according to Green [24]:

$$LM = \frac{nT}{2(T-1)}\left[\frac{\sum_{t=1}^{n}(\sum_{t=1}^{T} e_{it})^2}{\sum_{t-1}^{n}\sum_{t=1}^{T} e_{it}} - 1\right]^2 \qquad (6)$$

where LM is distributed as chi-squared with one degree of freedom under the null hypothesis.

$$H_0: \sigma_\mu^2 = 0$$

$$H_1: \sigma_\mu^2 \neq 0$$

where denotes the variance of individual effects in the sample. Under the null hypothesis, pooled-model is efficient and then, best fits the model.

Cross-sectional dependence and unit-root tests

There are some issues involving the panel data model, such as cross-sectional dependence between units. There is a need to figure it out in order to select the relevant estimators for the model. Two tests are applied in this paper to examine the cross-sectional dependence. Let us consider a standard panel-data model,

$$y_{it} = \alpha_i + \beta' x_{it} + u_{it} \qquad (7)$$

Where $i = 1, \ldots\ldots T$; x_{it} is a vector of regressors $(K \times 1)$; β is a constant parameter $(K \times 1)$; α_i: time-invariant individual nuisance parameters; u_{it} is the error-term and assumed to be independent and identically distributed over periods and across cross-sectional countries. Thus, the cross-sectional dependence test is to verify this assumption. Here are two tests that deal with it.

Pesaran (2004) proposed a test, so-called Pesaran's CD test which is represented as the following:

$$CD = \sqrt{\frac{2T}{N(N-1)}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right)} \qquad (8)$$

and

$$\hat{\rho}_{ij} = \hat{\rho}_{ji} = \frac{\sum_{t=1}^{T}\hat{u}_{ij}\hat{u}_{ji}}{\left(\sum_0^T \hat{u}_{it}{}^2\right)^{1/2}\left(\sum_0^T \hat{u}_{jt}{}^2\right)^{1/2}} \qquad (9)$$

$\hat{u}_{it}$ is the estimate of u_{it} in equation (9) and $\hat{\rho}_{ij}$ is the sample estimate of the pairwise correlation of residuals. Under the null hypothesis of no cross-sectional dependence, $CD \sim N(0,1) for\ N \longrightarrow \infty$ and T sufficiently large. The null hypothesis supposes the cross-sectional independence.

Also, there is another test developed by Friedman (1937), so called Friedman's test. It is based on Spearman's rank correlation coefficient. It is expressed as the following:

$$R_{ave} = \frac{2}{N(N-1)}\sum_{i=1}^{N-1}\sum_{j=t+1}^{N}\hat{r}_{ij} \qquad (10)$$

Where $\hat{r}_{ij}$: the sample estimate of the rank correlation coefficient of the residuals; R_{ave}: the average Spearman's correlation.

Friedman's test: $FR = (T-1)[(N-1)R_{ave} + 1]$

where FR is asymptotically χ^2 distributes with T-1 degrees of freedom, for fixed T as N gets large. Large value of FR indicates the presence of cross-sectional dependence. Under the null hypothesis, there is cross-sectional independence.

Later, the application of panel data model involves the unit-root test in order to check for stationarity. The common unit-root tests used in the panel data model are the tests proposed by Levin et al. (2002) and Im et al. (2003). However, these tests assume the independence of units. they are then unreliable in case there is cross-sectional dependence across units. As there is evidence for cross-sectional dependence, the test proposed by Pesaran (2007) is used to test unit-root. It does not require the assumption of cross-sectional independence. Based on Shariff and Hamzah (2015), this test is given by

$$CIPS = \frac{\sum_{i=1}^{N} CADF}{N} \qquad (11)$$

where CIPS denotes Cross Sectional augmented Im, Pesaran and Shin;

$$CADF_i = \frac{\left(y_{i,-1}^T \bar{M} y_{i,-1}\right)^{-1}\left(y_{i,-1}^T \bar{M} y_{i,-1}\right)}{\sqrt{\sigma_i^2\left(y_{i,-1}^T \bar{M} y_{i,-1}\right)^{-1}}} \qquad (12)$$

$where\ y_{i,-1} = (y_{i1}, \ldots, y_{iT-1})^T$; $\Delta y_{i,-1} = (\Delta y_{i2}, \ldots, \Delta y_{iT})^T$; $\sigma_i^2 = \frac{\sum_{t=1}^{T}\hat{e}_{it}^2}{T-4}$, with $\sigma_i^2 \hat{e}_{it} = \Delta y_{it} - \Delta\hat{y}_{it}$; $\bar{M} = I_t - \bar{H}(\bar{H}^T\bar{H})^{-1}\bar{H}^T$and $\bar{H} = (1, \Delta\,\bar{y}_t, \bar{y}_{t-1})$. I_t is a unit matrix of T*T, and H is the combination of dummy variables, average of cross section of the first difference of y_{it} and its first lagged value y_{it-1}. The asymptotic distribution of this test has non-standard distribution. The null hypothesis indicates the presence of unit-root test.

5. EMPIRICAL RESULTS

As the panel data models are considered in this paper, the cross-sectional dependence should be examined. Its presence may lead to the spurious results for some unit-root tests. The Pesaran (2004) and Friedman (1937) tests reported in table 3 indicate that there is cross-sectional dependence in panel data. Therefore, the selection of unit-root test should take into account this dependence. The unit-root test proposed by Pesaran (2007) takes into account this cross-sectional dependence and demonstrated that all variables are stationary (Table 2). Later, the estimators (fixed-effect, random effect and pooled-effect) are performed, and the results of each estimation appear to be slightly different in terms of significance but they have the same coefficient sign. The estimation results are reported in table 3. The specification tests between random and fixed-effect via Hausman test and between pooled effect and random-effect via Breusch-Pagan test are reported in Table 3 and indicated that fixed-effect best fits the observations. The result of Shapiro–Wilk which is the normality test (Table 3) rejected the null hypothesis that the residual is normally distributed. And Wooldridge test for autocorrelation supports the presence of autocorrelation in panel data (Table 3). Therefore, the estimation results are likely to be biased, as some assumptions of the panel data model are violated.

Table 2: Unit root test

	Psaran (2007)	
	CIPS	1% Critical value
GDPg	-3.02	-2.38
RDg	-3.257	-2.38
RENg	-4.216	-2.38
NRENg	-4.156	-2.38
LABg	-3.279	-2.38
Kg	-2.9462	-2.38

Table 3: Panel data estimation result of economic growth

	GDP growth		
Regressors	Fixed-effect	Random effect	Pooled effect
Kg	0.28***(0.011)	0.28***(0.011)	0.28*** (0.01)
RDg	0.04***(0.013)	0.04***(0.013)	0.04***(0.012)
RENg	0.01** (0.009)	0.02*** (0.009)	0.02*** (0.008)
NRENg	0.06***(0.013)	0.06***(0.014)	0.06*** (0.013)
LABg	0.24*** (0.06)	0.25*** (0.06)	0.25***(0.06)
Constant	1.09*** (0.11)	1.03*** (0.15)	1.05*** (0.16)
R^2	0.7243	0.7254	0.7259
Observations	399	399	399
CD test: Pesaran	17.85***	17.34***	
Friedman	109.68***	107.83***	
Breusch-Pagan	Chi2(5) = 32.03***		
Hausman test specification		Chibar2(01)= 35.3***	
Normality test	0.97***	0.978***	0.97***
Wooldridge test (autocorrelation)	4.062***		

Notes: ***, ** and * indicate significance level at 1%, 5%, and 10% respectively; the number in brackets is standard errors.

In fixed-effect results, the growth in gross capital formation, research and development, and labour, as expected, have positive coefficients, significant at 1%, meaning that they have significant and positive effect on economic growth. Such result is consistent with mainstream growth theory. Our aim is to evaluate the contribution of renewable to economic growth, and three models all confirm with a significant level that renewable energy positively contributes to the economic growth in OECD countries although many explanatory variables are included in the model. If renewable energy growth increases by one point, output growth would rise by 0.01 points. The coefficient associated with gross capital formation is 0.28, indicating that an increase of one point in capital stock growth will result in 0.28 points growth in output. Likewise, an increase of one point in the growth of research and development and in labour will increase the gross domestic product by 0.05 and 0.24 points, respectively. As for non-renewable energy, it has significant and positive impact on economic growth. One point of change in the growth of non-renewable energy use leads to 0.06 points of change in economic growth. The positive coefficient associated with renewable and non-renewable in the estimation result supports the view that these types of energy have a positive effect on economic growth in OECD countries. It is worth mentioning that although many countries in the sample have a low share of renewable energy in energy primary use, it is still significant. Our result is in line with some previous studies such as those carried out by Gozgor and al. (2018), Salim and al. (2014), Apergis and Payne (2010), Alvarez and al. (2017), in the sense that both renewable and non-renewable energy contributes positively to the economy.

6. CONCLUSION

This paper investigated the contribution of renewable energy to the economic growth of 26 OECD countries between the period 1996 and 2014. The panel data model is used in this analysis and the explanatory variables are selected according to the mainstream growth theory. Three models such as fixed, random and pooled-effect models are performed.

The specification test revealed that fixed-effect best fits the model, which corroborates the presence of individual effect and then, the assumption of least squares is no longer valid. The result demonstrated that all variables have significant and positive coefficients. They contribute to the economy positively. The contribution of capital, research and development, and labour to economic growth have been largely discussed in the mainstream growth theory.

The coefficient associated with renewable energy satisfies the 5% significance level although renewable energy has a relatively low share in the energy primary use in many countries, which is between 2% and 52% in the dataset. Renewable and non-renewable energy uses have both a positive effect on economic growth. This result comes from the fact that energy is an essential input for the economy. Nevertheless, the estimation results might suffer from the issues associated with the non-normality of residual and the presence of autocorrelation in the panel model, which could lead to the biased results.

Several works pointed out the benefit of using renewable energy to secure energy supply and to mitigate greenhouse emission, and this is the main difference between renewable and non-renewable energy sources. Non-renewable energy use enhances green gas emission, while renewable one helps a nation mitigate green gas emission. Since the result of empirical findings revealed that non-renewable energy has a significant positive impact on the economic growth of OECD countries over the periods between 1996 and 2014, the green gas emission is expected to increase over these same periods. For that concern, policymakers in these countries should focus on increasing renewable energy deployment in order to tackle climate change.

REFERENCES

Alvare-Herranz A., Balsalobre-Lorente, D., Shahbaz, M. (2017). Energy innovation and renewable energy consumption in the correction of air pollution levels. Energy Policy 105(2017) 386-397.

Apergis, N, Payne J. E. (2010). Energy consumption and economic growth: Evidence from panel OECD countries. Energy policy 38 (2010)656-660

Apergis, N., Payne, J. E. (2012). Renewable energy and non-renewable energy consumption-growth nexus: evidence from a panel error correction model. Energy Econ (2012):34(3):733-8.

Apergis, N., Tang, C. F. (2013). Is the energy-led growth hypothesis valid? New evidence from a sample of 85 countries. Energy Econ. 38 (2013) 24-31.

Bowden N., Payne, J. E. (2009). The causal relationship between U:S: energy consumption and real output: a disaggregate analysis. J Pol Model 2009:31(2):160-8.

Chen, Y., Wang, Z., Zhong, Z., CO2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. Renewable Energy 131 (2009) 208-216.

Dogan, E. (2016). Analyzing the linkage between renewable and non-renewable energy consumption and economic growth by considering structural break in time-series data. Renewable Energy (2016) 1126-1136.

Empora N., Mamuneas, T. (2011). The effect of emission on U.S. state total factor productivity growth. Rev Econ anal 2011:3:149-72.

Friedman, M. 1937. The use of ranks to avoid the assumption of normality implicit in the analysis of variance. Journal of the American Statistical Association 32: 675–701.

Gozgor, G., Lau C. K. M. (2018). Energy consumption and economic growth: New evidence from the OECD countries. Energy 153 (2018) 27-34.

Greene, W. H. (2012). Econometric Analysis. 7th Edition, Prentice Hall, Upper Saddle River.

Im, K. S., M. H. Pesaran, and Y. Shin. 2003. Testing for unit roots in heterogeneous panels. Journal of Econometrics

115: 53–74.

Inglesi-Lotz, R. (2016). The impact of renewable energy consumption to economic growth: A panel data application, Energy Economics, 53 (2016) 58 –63.

Ito, K. (2007). CO2 emissions, renewable and non-renewable energy consumption, and economic growth: Evidence from panel data for developing countries. International Economics 151 (2007) 1-6.

Jebli, M. B., Youssef, S. B. (2015). Output, renewable and non-renewable energy consumption and international trade: evidence from a panel of 69 countries. Renew Energy 2015:83:799-808.

Levin, A., C.-F. Lin, and C.-S. J. Chu. 2002. Unit root tests in panel data: Asymptotic and finite-sample properties. Journal of Econometrics 108: 1–24.

Lin, B., Moubarak, M. (2014) Renewable energy Consumption-Economic growth nexus for China. Renewable and Sustainable Energy 40 (2014) 111-117.

Long, X., Naminse, E. Y., Du, J., Zhuang, J. (2015). Non-renewable energy, renewable energy, carbon emission and economic growth in China from 1962 to 2012. Benew. Sustain. Energy Rev. 52 (2015) 680-688.

Organisation Economic Cooperation and Development (OECD). Primary energy share. Website: https://data.oecd.org/energy/renewable-energy.htm Last accessed: 18 January 2019

Payne, J. E. (2009). On the dynamics of energy consumption and output in the US. Appl Energy 2009; 86:575-7.

Pesaran, M. H. 2004. General diagnostic tests for cross section dependence in panels. University of Cambridge, Faculty of Economics, Cambridge Working Papers in Economics No. 0435.

Romer, P. (1990). Endogenous Technological Change, Journal of Political Economy, 1990, vol. 98, no. 5, pt. 2.

Sadorsky, P. (2009). Renewable energy consumption and income in emerging economies. Energy Policy 37, 4021-4028.

Salim, R. A., Hassan, K., Shafiei, S. (2014). Renewable and non-renewable energy consumption and economic growth. Energy economics 44 (2014) 350-350

Solow, M. R. (1956). A Contribution to the Theory of Economic Growth. The Quarterly Journal of Economics, Vol. 70, No. 1., pp. 65-94.

Soytas, U., Sari, R. (2006). Energy consumption and income in G-7 countries. J. Policy model 28 (7), 739-750.

Tang, C. H., Tan, B. W., Ozturk, I. (2015). Energy consumption and economic growth in Vietnam. Renewable and Sustainable Energy Reviews 54 (2016) 1506-1514.

Tugcu, C. T., Tiwari, A.T. (2016). Does renewable and/or non-renewable energy consumption matter for total factor productivity (TFP) growth? Evidence from the BRICS. Renewable and Sustainable Energy Reviews 65 (2016) 610-616.

Vouvaki, D., Xepapadeas, A. (2008). Total factor productivity growth when factors of production generate environmental externalities. MPRA Paper; 2008. P. 10237.

Shariff, Nurul Sima Mohamad and Hamzah, Nor Aishah (2015) "A Robust Panel Unit Root Test in the Presence of Cross Sectional Dependence," Journal of Modern Applied Statistical Methods: Vol. 14: Iss. 2, Article 14.