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Renewable Electricity Generation and Economic Growth: Panel-Data Analysis for OECD Members

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Abstract

Fossil fuels, which are considered to be one of the main reasons of some environmental problems such as global warming, climate change, and soon, are being replaced by alternative (renewable) energy sources in accordance with various agreements and binding resolutions. Nowadays, electricity consumption, the biggest input for economic and social development, is increasing constantly. Electricity generation from renewable sources is one of the objectives of sustainable development in order to satisfy this consumption demand. The study analyzes the relationship between electricity generation from renewable resources and economic growth in OECD countries for the period of 1980-2007 using panel-data method. The analysis indicates that there is a long term positive relationship between renewable electricity generation and economic growth, and a bidirectional (reciprocal) causality between these variables. An increase in electricity generation from renewable sources contributes sustainable development, as well as long term growth performance.

Keywords: Renewable energy production, Economic growth, Panel unit-root and cointegration tests.
JEL Classification Codes: Q42,C23

1. Introduction

Beginning from the industrial revolution of 1800s, various types of energy have been crucial for economic activities, especially for manufacturing, and industry in general. Yet energy shortages and crisis in 1970s led to searches for alternative sources and economical usages. These searches are at the centre of popular economic idea of sustainable development.

Fossil fuels, which are considered to be main reason of some environmental problems such as global warming, climate change, etc, are being replaced by alternative (renewable) energy sources in accordance with various agreements and binding resolutions. Nowadays, electricity consumption, the biggest input for economic and social development, is increasing constantly. Electricity generation from renewable sources is one of the objectives of sustainable development in order to satisfy this consumption demand.

Our main purpose is to analyze the relationship between electricity generation from renewable resources and economic growth. Using the data of OECD member countries for the period of 1980-2007, and applying panel-data methodology, we aim to see the direction of the relationship (if any), and then get some policy outcomes.

2. An Overview of the Related Literature

Examination of the relationship between electricity generation and economic growth constitutes an increasing concern in recent studies. In the related literature, generally the relationship between electricity consumption and economic growth is analyzed. These studies indicate that there is a strong relationship between electricity consumption and economic growth. Existence of a unidirectional relationship between these two variables has been set forth in many studies as well. Some of these studies are briefly reviewed below.

Altınay and Karagöl (2005) find out unidirectional causality from electricity consumption to economic growth in Turkey for the period of 1950-2000.

Yang (2000) points out bidirectional causality between energy consumption and economic growth in his study about Taiwan for the period of 1954-1957.

Yoo and Kwak (2009), in their study about Argentina, Brazil, Chile, Colombia, Ecuador, Peru and Venezuela, underline the existence of a unidirectional causality from short term electricity consumption to economic growth in Argentina, Brazil, Chile, Colombia and Ecuador. They find out bidirectional causality for Venezuela, and no causality for Peru between these two variables.

Soytaş and Sarı (2007) analyzed the relationship between energy and industrial production in Turkey. In this study, unidirectional causality between electricity consumption for production and added value were found out.

Sadorsky (2009), in his study dated 2009, analyzed the relationship between renewable energy consumption and national income in 18 developing countries for the years 1994-2003 using panel data analysis. Sadorsky concluded that % 1 increase in real income, increases the energy consumption by % 3,5 in the long run.

Apergis and Payne (2009), in their 2009 study for 20 OECD countries, for the period of 1985-2005 using panel data method, assert the existence of unidirectional long term relationship between real GDP, renewable energy consumption, real fixed capital investment and labor force. They also found out bidirectional causality between renewable energy consumption and economic growth for both short and long term.

The relationship between electricity generation and economic growth has been rarely studied in the literature. Causality relationship is from electricity generation to economic growth and/or from economic growth to electricity generation. The crucial question in this debate is the following: Does the electricity generation affect economic growth or economic growth increase the electricity generation? In both cases, the important thing is the way policies are determined and implemented. If the existence of unidirectional causality from electricity generation to economic growth is assumed, any decrease in electricity generation may lead a certain degree of decrease in economic growth. On the other hand, if the existence of unidirectional causality from economic growth to electricity generation is assumed the policies aimed at decreasing electricity generation may not have adverse effects over economic growth. Lastly, providing that there is no causality between these two variables any increase in electricity generation would not affect or change economic growth. Generally, the relationship between electricity generation and economic growth is well established when most effective electricity generation policies are implemented (Yoo and Kim, 2006).

Renewable electricity generation constitutes the basis of alternative energy policies which takes place among the necessary factors for sustainable development. Electricity to be generated from renewable resources would ensure sustainable economic growth.

Morimoto and Hope (2004), in their study on "The impact of electricity supply on economic growth in Sri Lanka" for the period of 1960-1998, found out that change in electricity supply leads important changes in real GDP.

Another example of testing the relationship between electricity generation and economic growth is provided by Yoo and Kim (2006). In their study on "Electricity generation and economic growth in Indonesia", the authors test electricity generation and economic growth, using time series for the period of 1971-2002, and causality from economic growth to electricity generation is found out in the causality test conducted for Indonesia.

Ghosh (2009), examines the issue using Indian data for the period of 1970-2006. In his paper, dated 2009, and titled "Electricity supply, employment and real GDP in India: Evidence from cointegration and granger-causality tests", the author finds out a unidirectional short term causality from economic growth to electricity supply.

Halkos and Tzeremes (2009) analyze the data of 42 countries around the world and East Asia, focusing on electricity generation and economic performance of the countries for the period of 1996-2006 making use of panel data methodology. This study indicates an inverse U-type relationship between electricity generation and economic efficiency, depending on the national economic structure.

3. Method: Panel - Data Analysis

Different types of data are used in empirical studies conducted in economics. These data can be analyzed only with convenient models and methods. Separate analysis can be managed using time series and cross-section data. The method based on the estimation of economic relations using cross-section data which have time dimension is called "panel data analysis". In this analysis, data sets which have both time series and cross-section dimensions are composed by gathering data at both levels, as the majority of the recent studies in the related literature benefiting from data sets obtained through combining time and cross-section series.

Baltagi (1995), lists the superiorities of panel data method as follows:

i. Since panel data is about individuals, firms, countries, etc throughout time, existence of heterogeneity in these units seems quite certain.
ii. As panel data method integrates cross-section and time series observations, more data and variety, high degree of independence and efficiency and less dependence between variables can be acquired.
iii. Panel data method leads less *multicollinearity* problem between variables.
iv. Panel data method provides the opportunity to carry out econometric analysis even in the cases where insufficient time serial and/or cross-section observations exist.

For panel data analysis of this study, a simple linear model with one independent variable is defined as follows:

$$y_{it} = \alpha_{it} + x_{it}\beta_{it} + \mu_{it} \qquad \text{(model 1)}$$

i = 1, 2,..., n, number of cross-section units,
t = 1, 2, …, t, time interval,
y_{it} = t value of the i'th unit of dependent variable at the time of "t",
x_{it} = value of the i'th unit of independent variable at the time of "t",
μ_{it}: error term,
α_{it} = value of "i" unit of "α" at "t" period,
$\beta\ it$ indicates the coefficient of independent variable.

In panel data analysis, the models in which change of coefficients takes place according to units and time is called as fixed effect models. Unidirectional fixed effect models are used if fixed effect models deal only with differences between units. If fixed effect models take the differences into account which prevail with respect to units and time then bidirectional fixed effect models are applied (Yılgör, 2008).

Changes emerging with respect to units and time are included into the model as a component of error term in random effects models. The aim to overcome the problem of "loss of degree of freedom" which is commonly encountered in fixed effect models is underlying explanation. In random effects model, existence of error components but not coefficients which are pertaining to units or units and time is crucial. Additionally, in random effects models, section of the observed sample takes into account not only the effects of the differences occurring with respect to units or time, but the external effects out of sample (Hsiao, 1986).

4. Variables and Data Set

Main objective of this study is to test the relationship between electricity generated from renewable resources and economic growth. Electricity generation from renewable resources is the production of energy from hydraulic, wind, sun, biofuel, geothermal energy and household and/or industrial wastes. Electricity generation is measured as giga-watt hour. The multivariate frame-work includes real GDP in constant 2000 US dollars, is taken as a base for economic growth data. Data used in the study were obtained from OECD (Organization of Economic Cooperation and Development), EIA (Energy Information Administration) and Eurostat databases.

Data set includes 30 OECD countries for the period of 1980-2007, covering 28 years. (For Slovakia, electricity generation includes 1993-2007, GDP includes 1992-2007; for Poland and Czech Republic, GDP includes 1990-2007; for Hungary, GDP for 1991-2007). The countries forming the sample are; Australia, Austria, Belgium, Czech Republic, Canada, Japan, Denmark, Mexico, Finland, France, Hungary, Germany, New Zealand, Poland, Greece, South Korea, Slovakia, Iceland, Italy, Ireland, Luxembourg, Holland, Norway, Portugal, Spain, Sweden, Switzerland, England, USA and Turkey. Data set of the study is unbalanced, and covers 797 observations for GDP and 827 observations for electricity generation.

The model used in this study is as follows:

$$EB_{it} = \alpha_{it} + x_{it}\, ELK_{it} + \mu_{it} \qquad \text{(model 2)}$$

EB_{it}: Change of GDP series with respect to previous year which means economic growth,

$ELK_{it:}$ Series of electricity generated from renawable resources

i: 1, 2, …., 30, number of countries

t: 1980, 1981, …., 2007, time period.

5. Panel Unit Root Test

In a standard regression model, unit root comes out naturally. Assumptions of classical regression model set forth that series of both dependent and independent variable should be stationary and errors should have a zero mean and finite variance. "Spurious regressions" may emerge in the case of non-stationary variables. In spurious regression, even though meaningful t statistics exist, parameter estimation results would be meaningless (null) regarding economy. Besides, traditional statistical deduction tests would be invalid. Consequently, before commencing an econometric analysis, unit root test for the series of model should be realized, and these series should be checked to see whether they are stationary or not. In non-stationary series, overcoming this problem is important in order to avoid spurious regression, and get valid conclusions about economy.

At Table-1 and Table-2, unit root test results of the series used in the model are indicated according to different approaches. Results are obtained via econometrics packet programme "E-views 6.0". t-statistics and probability results of unit root test results applied to the variables' levels show that series used in the econometric analysis are not stationary and includes unit root problem. Therefore, first differences of the series were studied and inquired.

At Table-1 and Table-2, first differences of the series are explored for ΔELK and ΔEB variables. It is concluded that first differences of the series are stationary and "spurious regression" problem would not be encountered in any model formed with these series. Therefore, co-integration test is implemented following the unit root tests for the series of model.

Table 1: Panel Unit Root Test Results for ELK variable

	LLC	*IPS*	*ADF*	*PP*
ELK	6,47751	6,117	70,0058	85,6795**
ΔELK	-20,9092*	-21,8933*	512,185*	632,728*

Notes: * Significance level at the 1%, ** Significance level at the 5 %.

Table 2: Panel Unit Root Test Results for EB variable

	LLC	*IPS*	*ADF*	*PP*
EB	9,95288	15,8671	4,21818	1,48652
Δ*EB*	-6,67424*	-8,65949*	197,044*	191,346*

Note: *Significance level at the 1 %.

6. Cointegration Test

Empirical studies reveal that most of the macroeconomic time series are not stationary. Various methods are suggested to solve "spurious regression" problem which is encountered among the series including unit root. One of these methods is to insert differences of these series into regression. Even in such a case, a new problem arises as well. This technique leads loss of data which are quite important for long-term equilibrium. Since the first differences of the variables are used in the model, probability of observing long-term relationship between these variables would be eliminated. This is the point of origin for co-integration analysis. Co-integration theory is employed to seek long-term equilibrium relationship between variables and allows estimating directly the existence of equilibrium relationship which is implied in economic theories.

The test offered by Pedroni (2004) states that direct implementation of panel unit root tests to regression residuary would not be effective, since explanatory variables are not external and distribution, residuary, etc of estimated coefficients are dependent. In this case, it is preferable to have heterogeneity in the alternative in co-integration test procedure. Pedroni (2004) test allows for co-integration heterogeneity.

Co-integration system of this study is as the following:

$$y_{it}=\alpha_i+\delta_{it}+\gamma_t+\beta_{1i}X_{1i,t}+\beta_{2i}X_{2i,t}+\ldots\ldots+\beta_{mi}X_{mi,t}+e_{i,t} \quad \text{(model 3)}$$

$t = 1, \ldots, T;\ i = 1, \ldots, N;\ m = 1, 2, \ldots, M$

In this system, T is the total number of observations during time; N is the total number of individual units in panel, and M is the number of regression variables. In the above equation, X_i, is one component of specific intersection; γ_t, is joint time dummy of all panel components, and δ_{it}, is determining time trend. All of them are features of individual panel membership.

Table 3: ELK and EB Pedroni Cointegration Results

	Statistics	*Prob*
Panel *v*-statistics	-3,252969*	0,0020
Panel rho statistics	-8,532689*	0,0000
Panel PP statistics	-19,60203*	0,0000
Panel ADF statistics	-1184333*	0,0000
Grup rho statistics	0,0863969*	0,2747
Grup PP statistics	-7,129618*	0,0000
Grup ADF statistics	-2,945626**	0,0052

Notes: * Significance level at the 1%, ** Significance level at the 5%.

At Table-3 Pedroni conitegration test is applied as primary differences of ELK and EB series are found to be stationary. According to these findings, H_0 hypothesis (no cointegration between series) will be rejected, since the test statistics are meaningful. Results of all other tests are statistically meaningful apart from Group rho-Statistic test. According to the results of this test, there is a relationship between EB and ELK variables in the long run.

Table 4: ELK and EB Kao Cointegration Results

	T statistics	***Prob***
ADF	-5,500028*	0,0000

Note: *Significance level at the 1%.

At Table-4 according to Kao and Fisher cointegration tests, H_0 hypothesis (no cointegration between series) would be rejected, since test statistics are meaningful. Therefore, alternative hypothesis will be approved, and existence of relationship between EB and ELK variables in the long-run will be noted.

7. Causality Test

Holtz Eakin causality test is reflected in VAR model as the following (Holtz-Eakin, Newey and Rosen 1988):

$$EB_{it} = \alpha_0 + \sum_{j=1}^{m} \alpha_j EB_{it-j} + \sum_{j=1}^{m} \delta_i ELK_{it-j} + f_{yi} + u_{it} \quad \text{(model 4)}$$

$$ELK_{it} = \beta_0 + \sum_{j=1}^{m} \beta_j ELK_{it-j} + \sum_{j=1}^{m} \gamma_i EB_{it-j} + f_{Xi} + \vartheta_{it} \quad \text{(model 5)}$$

Here, Y_{it} and X_{it} are cointegrated variables. i= 1, 2, …, N are cross-sectional panel data; ϑ_{it} and u_{it} are error terms; f_{Xi} and f_{yi} are individual fixed effects, and m is the length of lag. When the first differences of the models are taken in order to remove the fixed effect, the equations turn to be as follows:

$$\Delta EB_{it} = \sum_{j=1}^{m} \beta_j \Delta EB_{it-j} + \sum_{j=1}^{m} \delta_i \Delta ELK_{it-j} + \Delta u_{it} \quad \text{(model 6)}$$

$$\Delta ELK_{it} = \sum_{j=1}^{m} \beta_j \Delta EB_{it-j} + \sum_{j=1}^{m} \gamma_i \Delta ELK_{it-j} + \Delta \vartheta_{it} \quad \text{i=1,2.....30, j=1,2} \quad \text{(model 7)}$$

Tested H_0 hypothesis,

$\delta_i = 0$, i = 1, 2, …, 30

$\beta_i = 0$, i= 1, 2, …, 30

According to Holtz Eaken and Newey Rosen causality test, economic growth is considered as the first dependent variable. First degree differences of the data are calculated in order to overcome simultaneity problem, and there exists a relationship between each country's error terms in panel data system. To eliminate this obstacle, instrument variable method is benefited. Causality test is used as GMM estimation. Second degree least squares are used as GMM weighting and cross-section weight as the EGLS weighting. Possibility of facing to changing variance and auto-correlation is the reason. Wald test is applied to determine meaningfulness of lagged values (Yılgör, 2008). Likewise, all abovementioned phases are also applied, when electricity generation is taken as dependent variable, and the results are listed in Table-5.

Table 5: GMM estimation and Wald test results

Coefficient Estimations	*EB (1 lagged)*	*ELK (1 lagged)*
GDP_{it-1}	-0,342391 (0,040247)	-0,024089 (0,026290)
ELK_{it-1}	-0,005661 (0,009799)	0,737566 (0,087001)
GDP_{it-2}	-0,137640 (0,040596)	0,008495 (0,028053)
ELK_{it-2}	0,009862 (0,008519)	0,119252 (0,082710)
Wald test χ_h^2 *Prob*	8,13 0,0443	6,57 0,0866

Table 6: Holtz Eaken Causality Anlaysis

Direction of causality	*F value*	*Probability Value*	*Conclusion*
$\Delta EB \rightarrow \Delta ELK$	2,193	0,0877	*** Exists
$\Delta ELK \rightarrow \Delta EB$	2,710	0,0443***	Exists

As shown by Table-6, there are exists a bidirectional causality relationship from economic growth to electricity generation and from electricity generation to economic growth in OECD countries for the period of 1980-2007. In other words, for the period observed, any increase in economic growth increases electricity generation and any increase in electricity generation leads economic growth in OECD countries.

8. Conclusion

Electricity takes place among the most important inputs for industry and production. Per-capita electricity consumption is one of the indicators for the level of development of different countries. Predominantly, electricity is generated from fossil fuels. Electricity generation from renewable resources is less than fossil fuels. Excessive set up costs, low level of sustainability and productivity, insufficient storing capacity can be listed as the main reasons not to prefer electricity generation from renewable resources. Today, it is obvious that price levels of electricity generated from fossil fuels and renewable resources are not much differing from each other. Rate of electricity generation from renewable resources is 17-20 % in overall electricity generation from all resources during the observed years. The rate of nuclear resources doubled from 10 % to 20 % showing no change for the last decade. For the period of 1980-2008, amount of electricity generated in OECD countries also doubled and electricity generated from renewable resources performed 70 % increase.

In this study, we analyzed the relationship between economic growth and electricity generation from renewable resources in 30 OECD countries, using panel data method for the period of 1980-2007. Unit root tests proved that primary differences of variables are stationary, and do not include unit root. Pedroni, Kao and Fischer cointegration tests conducted subsequently demonstrated that there exists a long term meaningful relationship between the series. Bidirectional causality between electricity generation and economic growth was found out by Holtz-Eakin causality test. Results of this study asserts that the relationship between electricity generation and economic growth is statistically meaningful in the long run. Therefore, countries should implement policies aiming at increasing electricity generation in order to meet increasing electricity demand. Exhaustion problem of fossil fuels and fluctuating speculated prices lead countries seek alternative energy resources. Especially in line with the related UN decisions, electricity generation from renewable resources must be increased, production of less-energy consuming products should be encouraged, and awareness of energy saving must be developed.

According to the causality test results conducted in this study, renewable electricity generation affects economic growth positively and economic growth gives opportunity to increase electricity generation from renewable resources which have gained significance among all energy resources in OECD countries. Therefore, it can be argued that, investments for renewable electricity generation will ensure clean and environment-friendly electricity generation, boosting economic growth. In this regard, governments are adviced to encourage and promote renewable electricity generation using tax exemptions and incentives for more investment so that renewable energy resources can be diversified. As long as importance and use of renewable resources for economic growth increases, countries will likely depend on external resources. It is a fact that OECD members are already very much dependent on external resources for non-renewable energy. Lastly, improving renewable energy production would decrease price fluctuations in international petroleum-natural gas markets and environmental degradation stemming from carbon emissions in the long run.

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