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Article

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International Journal of Energy Economics and Policy

Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Huseynli, Bahman (2024). Analyzing the relationship between renewable energy sources, economic growth and energy consumption in Greece. In: International Journal of Energy Economics and Policy 14 (2), S. 89 - 95.
https://www.econjournals.com/index.php/ijeep/article/download/15356/7748/36334.
doi:10.32479/ijeep.15356.

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(2), 89-95.

Analyzing the Relationship between Renewable Energy Sources, Economic Growth and Energy Consumption in Greece

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Received: 09 October 2023 **Accepted:** 15 January 2024 **DOI:** https://doi.org/10.32479/ijeep.15356

ABSTRACT

Renewable energy sources are one of the important economic factors of today. Energy resources have a great place for economic growth. There are many types of renewable energy sources, each of which is one of the indispensable elements for the development and development of countries. In this study, which measures the importance of energy consumption within the scope of economic growth and renewable energy, the effects of renewable energy sources and economic growth on energy consumption are investigated. In the study, the relationship between renewable energy sources, economic growth and energy consumption was examined by making panel cointegration analysis for Greece between 1997 and 2015. According to the results of the analysis, the panel data model established is significant at the 95% level. The independent factors explain 78% of the dependent variable's variation, according to R^2. Energy consumption and renewable energy consumption were negatively correlated. A significant and positive relationship was found between economic growth and energy consumption at the 95% confidence level. An 1% increase in economic growth will increase energy consumption by about 15%. This result obtained because of the estimation also supports the theoretical expectation.

Keywords: Renewable Energy, Energy Economics, Energy Consumption, Economic Growth, Greece
JEL Classifications: Q42, O13, O11, C50

1. INTRODUCTION

The world's ecology is faced with a dilemma due to the rise in energy consumption. This causes lengthier droughts, increasing sea levels, and the advent of heat waves, all of which have detrimental effects on the ecosystem (Li et al., 2023). The rise in human demands has a direct impact on the escalation of production levels. The provision of energy resources is essential to fulfill the production requirements necessary to meet the diverse needs of humanity (Huseynli, 2022a). While the impacts of human activity are well recognized, Urry (2015) discovered that greenhouse gas emissions, such as carbon dioxide (CO2), are increasing in the atmosphere.

Nonetheless, nations that have access to both conventional and renewable energy sources might see economic development. According to three viewpoints on the relationship between energy and development (Kalyoncu et al., 2013; Chang, 2015),

- The first perspective asserts that energy is a production input, creating a causal link between energy consumption and economic expansion (Stern and Cleveland, 2004)
- According to a second viewpoint, economic expansion has an adverse impact on energy consumption since the causal relationship is reversible (Aziz, 2011; Toman and Jemelkova, 2003)
- The third perspective holds that the link is bidirectional, meaning that both economic growth and energy consumption are impacted by one other (Aziz, 2011).

The appraisal of a nation's output and economic success also heavily considers energy consumption. Economic expansion is one of the elements that raises energy demand. Sadorsky (2012) asserts that, assuming a positive correlation between energy production and consumption, unidirectional causation, or neutrality from GDP to energy implies that energy-saving strategies may be implemented without impairing economic development. Energy conservation programs that limit energy usage will slow economic development because there is a one-way causal relationship between energy and GDP, or feedback between energy and GDP.

In developed nation economies, Shahbaz et al. (2018) looked into the strength of the causal link between sustainable energy usage and globalization. According to Gajowniczek and Zbkowski (2014), estimates of energy consumption not only assist utilities in allocating resources and implementing control measures to balance energy supply and demand, but they also assist consumers in better understanding their own energy consumption patterns and anticipated future needs.

In general, renewable energy, commonly referred to as "clean energy," is defined as energy derived from sun, wind, wave, geothermal, tidal, and wood waste as well as plant resources (biomass) (IRENA, 2015). Renewable energy comes from limitless or renewable sources and is produced by natural processes like the sun's rays and the wind. Ocean power, solar, wind, and geothermal energy are the primary sources of renewable energy. The proportion of renewable energy in the power, heating-cooling, and transportation sectors is considerably rising. The most useful, alluring, and unique aspect of renewable energy is its ability to contribute to three crucial areas: long-term economic development, energy security, and pollution reduction (Mukhtarov et al., 2023).

Such initiatives are backed by the states since growth based on renewable resources is more environmentally friendly. One of the top priorities on the agendas of many nations is the switch to renewable energy. The energy transition is a plan for changing the global energy sector such that carbon-neutral energy sources replace their fossil fuel-based equivalents, according to the Renewable Energy Agency (IRENA, 2015). This procedure should be finished by the second part of the century, according to the roadmap.

The link between renewable energy sources, economic growth, and energy consumption has been investigated using an econometric technique in light of all of these factors. Panel cointegration analysis was used to assess the specified econometric model for Greece between 1997 and 2015.

In the southernmost point of the Balkan Peninsula, Greece is a nation that belongs to the European Union. The nation's distinctive geographic features—many islands, a hilly and rocky mainland, and the resulting uneven population distribution—create additional obstacles to the construction of the energy infrastructure required to meet the goals of the country's national energy strategy. Greece is separated from the rest of Europe by all except Italy (Lazarou et al., 2008).

The tourist and shipping sectors, banking and finance, manufacturing and construction, and telecommunications are among Greece's primary economic activities.

2. LITERATURE REVIEW

2.1. Energy and Economic Growth

People buy more energy as a result of improved economic development, which raises their percentage of energy consumption. Energy output doubles along with economic expansion, which supports further economic development (Sadiq et al., 2023). There exists a substantial body of research pertaining to the relationship between energy and economic development. The initial examination of the relationship between energy and GDP through cointegration analysis was conducted by Eden and Jin (1992).

In the research by Lee and Chang (2008), the link between energy, GDP, and capital in 16 Asian nations over thirty years was examined using panel data cointegration techniques. Using panel data cointegration techniques, Lee et al. (2008) investigated the link between energy, GDP, and capital during the previous four decades in 22 OECD nations.

In the research done by Özturk et al. (2010), it was shown that in low-income nations, GDP is long-run Granger causally related to energy consumption, while in middle-income countries, the relationship is bidirectional. Using a panel vector error correction model of GDP, energy usage, and energy prices for 26 OECD countries (1978-2005), Costantini and Martini (2010) demonstrated that, in the short term, energy prices affect GDP and energy consumption. Tsani (2010), on the other hand, looked at time series data for Greece from 1960 to 2006 to investigate the causal link between discrete and aggregated levels of economic growth and energy usage. Also, 20 OECD nations' economic development and usage of renewable energy were analyzed in a multivariate framework by Apergis and Payne (2010a) during the years 1985-2005.

According to research by Shahbaz et al. (2012), there is a bidirectional Granger causal relationship between economic growth and power use. A nonlinear energy demand model was developed by Lee and Chiu (2013) utilizing information from 24 OECD nations, an error correction term, and a smooth transition regression model. Altunbas and Kapusuzoglu (2015), however, examined the connection between GDP and energy usage in England between 1987 and 2007.

According to Ali et al. (2016), economic growth and energy consumption both have a one-way positive causal relationship with CO_2 emissions in Nigeria. Fang and Chang (2016), on the other hand, looked at the causation and cointegration relationship between energy usage and economic performance over the years 1970-2011 in 16 countries around the Asia Pacific. Moreover, Mirza and Kanwal (2017) looked at the causal relationships between CO_2 emissions, economic growth, and bidirectional evidence of energy consumption.

In research published in 2018, Acheampong (2018) looked at mixed causalities between economic growth and carbon emissions for 116 nations across several geographical groupings between 1990 and 2014. On the other hand, Fang and Wolski (2021) looked at the relationship between China's GDPs and both aggregate and discrete energy usage from 1965 to 2014. The phenomenon of economic growth holds considerable importance in the overall progress and welfare of a nation. The pursuit of economic progress is a universal objective for all nations. As a result, a variety of macroeconomic variables will influence economic development (Huseynli, 2022b). Moreover, the impacts of GDP and trade openness on electricity consumption were looked at in research by Yilmaz and Cowley (2022). Nevertheless, research by Bairagi and Ghosh (2022) used a 43-year yearly data set between 1972 and 2014 to examine the causal relationship between energy consumption and socioeconomic growth in the Indian subcontinent.

2.2. Energy Consumption

Several studies have looked at the connection between energy consumption and economic growth. In reaction to the shocks caused by the rise in oil prices in the 1970s, research was conducted to determine the link between energy consumption and GDP (Sadorsky, 2012). It is said that substantial economic growth stimulus maintains the expansion and sustainability of energy consumption by substituting alternative energy sources (Li et al., 2021; Pegkas, 2020). Yet, a lack of energy has a detrimental effect on a country's social life and economic performance across a number of areas, including transportation (Yildirim, 2017).

Nachane et al. (1988) discovered that there is a bidirectional causative relationship between commercial energy consumption and production for Brazil, Colombia, and Venezuela and a unidirectional causal relationship between commercial energy consumption and real GDP per capita for Argentina and Chile. Moreover, Murry and Nan (1993) discovered that there is a unidirectional causal relationship between Colombia's real GDP and power usage.

According to research by Mehrara (2007), there is a one-way causal relationship between real GDPs per capita and commercial energy consumption per capita for a panel of 11 oil-exporting nations, including Ecuador and Venezuela. By reducing vehicle idling and switching to compact fluorescent lights instead of incandescent ones, for example, Vandenbergh et al. (2007) identified seven actions that have the potential to result in significant emissions reductions at a low cost to the government and net savings for individuals (CFLs).

According to Chontanawat et al. (2008), there is a one-way causal relationship between real GDPs per capita and energy consumption per capita in Chile, Colombia, and Uruguay as well as a one-way causal relationship between real GDPs per capita and energy consumption per capita in Bolivia, Paraguay, Peru, and Venezuela. For Argentina and Brazil, however, there was a bidirectional causal relationship observed, but not for Ecuador. A panel of nine South American nations—Argentina, Bolivia, Brazil, Chile, Ecuador, Paraguay, Peru, Uruguay, and Venezuela—was studied by Apergis and Payne (2010b), who looked at both short- and long-term factors ranging from energy consumption to economic development. There was proof of long-term causation.

Sunikka-Blank and Galvin (2012) looked at the available data on 3400 German households and compared the estimated energy performance ratings (EPR) to actual measured usage. The study's findings showed that, on average, building occupants use 30% less heating energy than the estimated rating.

The link between economic development, sustainable energy usage, and carbon emissions in three North African nations was examined in the research undertaken by Kais and Ben Mbarek (2017). A visual analysis method, however, was created by Guo and Meggers (2018) that can visually assess how effective energy consumption is for thermal comfort.

3. RESEARCH METHODOLOGY

3.1. Purpose and Data Set

The aim of this study is to examine the relationship between renewable energy sources, economic growth, and energy consumption, using the data between 1997 and 2015 for Greece. Panel data method was preferred for the analysis. The data set used in the analyses was obtained from the World Bank.

3.2. Analysis Method

"Time series data," which includes the change in the values of variables from time series, cross section and panel data types used in econometric analyses according to time units such as day, month, season, and year; "cross-sectional data" collected from different units at a particular point in time; What is expressed as bringing together cross-sectional observations in a certain period is expressed as "panel data". Panel data analysis is defined as a data analysis method consisting of N units and T number of observations corresponding to each unit (Yerdelen Tatoğlu, 2018).

The data formed by combining time series and cross section data is called "Longitudinal Data" or "Pooled Data." Since the time and cross-section dimensions of this type of data may differ, the pooled data showing the change of the same set of units according to time, where the cross-section units remain unchanged, are called "panel data". In short, pooled data with the same cross-section units are panel data. Panel data is handled in two ways, as balanced panel, and unbalanced panel data. If the observations belonging to *T* number of periods are the same for all observations in the horizontal section for *i=1, 2, 3,…, N,* it is defined as "balanced panel data", and if the observations belonging to at least one unit in the panel data are different, it is defined as "unbalanced panel data" (Güriş and Yaman, 2018). The regression model estimated with panel data can also be defined as the "panel data model." Panel regression model in which the dependent variable is *Y*, and the explanatory variable is *X*, with the expression *i* for the units and t for the time period (Güriş and Yaman, 2018):

$$Y_{1t}=\alpha_{1t}+\beta_{it} X_{it}+\mu_{it} \quad (1)$$

In the above model, *i=1, 2, 3., N* denotes the unit of the panel data segment and *t=1, 2, 3., T* denotes the period. In the model, ⍰t is the error term, ⍰ it is the constant parameter, and ⍰ it is the slope parameter. In this case, the panel linear regression model with *k=1, 2, 3,…, K* parameters:

$$Y_{1t}=\alpha_{1t}+\beta_{2it} X_{2it}+\cdots+\beta_{kit} X_{kit}+\mu_{it} \quad (2)$$

Panel data has some advantages compared to cross-sectional or time series data, and for this reason, the reasons for using panel data are included in the literature. Panel data, which combines the cross-section data with the time series, is expressed as a data set that gives more information, has less co-linearity between its variables, has a higher degree of freedom and is more effective. In addition, it is stated that the effects that cannot be observed only in the cross-section data or only in the time series data can be better measured and revealed in the panel data set. Finally, it is shown as another advantage of panel data that more accurate inferences are made for model parameters, that it has a higher capacity than a single cross-section or time-series data in determining the complexity of individual behavior, and simplification of calculation and statistical inferences (Baltagi, 2005; Gujarati and Porter, 2010; Hsiao, 2007).

Panel data models can be examined under two main headings: Fixed-Effects Models and Random-Effects Models. The coefficients of fixed effect models vary according to units, time or units and time. If these models are created to determine the change according to time or units, "Single Factor Fixed Effect Model"; Although it was created to determine the change according to time and units, it can be defined as "Two-Factor Fixed Effect Model". In random-effect models, unlike fixed-effect models, changes in units or time are added as a random variable as a component of the error term in the model. Random effect models are also evaluated as single-factor and two-factor random effect models depending on the number of effects examined (Güriş and Yaman, 2018).

Unlike other panel unit root tests, Hadri (2000) test tests the stationary null hypothesis against non-stationary alternatives. According to the test, two models with cumulative and deterministic trends are analyzed. For the test, hypotheses such as "H_0: ? = 0" and "H_1: ? > 0" are formed in panel unit root research. According to the Im et al. (2003) panel unit root test, it is expressed as the development of the Pesaran et al. (1997) test by evaluating whether the error term has a correlation or not, the T time series and the N time dimension being finite and infinite. The hypotheses of the test are "H_0 =: ? = 0" and "H_1: ? > 0", and *"H_0: There is a panel unit root for all i-section units"*, *"H_1: There is no panel unit root for some i"*.

The Breusch-Pagan Langrange Multiplier LM Test (1980) measures the correlation between units in the fixed effects model in panel data analysis. This test can be used to test whether there is a correlation between the residuals of the cointegration or error correction model established for each unit.

The Breusch-Pagan Langrange Multiplier LM Test can be used to choose between pooled and random effect panel data models. If "*probe=0*" because of the test, the H_0 hypothesis that the variance of the unit effect is equal to zero will be rejected. Therefore, it is concluded that the unit effects are significant, and it would not be appropriate to use the pooled EKK (POLS) method (Zeytinoğlu et al., 2018).

LCL regression is a multivariate statistical method consisting of least squares and multiple straight regression methods. Least squares were developed by Wold as an econometric method in the 1960s. However, it was started to be widely used by his son Svante Wold with studies in the field of chemometrics. For its first use in statistics, studies by Höskuldson (1988) and Naes and Martens (1988) can be given as examples. This method can be used to eliminate the multicollinearity problem, in cases where the variables are more than the number of observations or the number of observations is more than the number of variables, and it allows working with more than one dependent variable. In the LCL analysis, explanatory variables with multiple linear connections between them are reduced to fewer components than the number of explanatory variables, which will explain both the change in the dependent variable and the change in the explanatory variables, with the help of algorithms. The common goal of the algorithms is to obtain components that will maximize the covariance matrix.

4. ANALYSES AND RESULTS

After reviewing the summary statistical tables for the data set used in the study, the stage of establishing the necessary model for analysis was started. Based on the information above, we can express the model created as in Equation 3.

$$Lenergy\ use=\beta_0+\beta_1\ renewable\ energy\ output+\beta_2\ LGDP+\mu \quad (3)$$

The combined and separate significance of each effect in the model were tested with the Lagrangian Multiplier (LR) test and the test results are summarized in Table 1. According to the test results given in Table 1, the basic hypothesis testing the significance of the three effects together was not rejected. Here it does not appear that the alternative hypotheses differ from zero. In the second stage, each effect was tested separately. According to the findings, unit effect and time effect were not found significant. Therefore, it can be said that this analysis group has homogeneous properties and does not show heterogeneity according to unit and time.

The White Test was used for heteroscedasticity between datasets. The White Chi-square test statistic was found to be 5.25 and it was concluded that the homogeneity error variance in the data set was meaningless at the significance level and the null hypothesis should be accepted (Table 2).

According to Wooldridge (2002) autocorrelation test statistic, the null hypothesis of "There is no autocorrelation" in the model was rejected. In other words, an autocorrelation problem was observed between the error terms in the equations (Table 3).

If there is more than one independent variable, the correlation between independent variables is expected to be low. When the correlation is high, the problem arises that the independent variables are not actually independent, and it becomes difficult

Table 1: Likelihood ratio (LR) test results

Names of tests	LR statistics	Probability value
Unit and time impact	0.00	1.0000
Unit impact	0.00	1.0000
Time effect	0.00	1.0000

to determine to what extent the independent variables affect the dependent variable. In panel data models, first, it is necessary to check whether there is a multicollinearity or not (Sarıkovanlık et al., 2019). Inflation factor analysis of variance was applied to test the cross-sectional dependence.

Variance inflation factor (VIF) values of the variables were also examined, and when the same situation was measured with VIF values, it was understood that there was no multicollinearity. The results of VIF values are given in Table 4.

In case of deviations from the variance, estimation was made with the resistant model. According to the analysis results given in Table 5, the panel data model established is significant at the 95% level. According to the R2 value, the independent variables explain about 78% of the change in the dependent variable. According to the model, there is a statistically significant relationship between energy consumption and renewable energy production and the dependent variable of economic growth. There is a negative relationship between renewable energy production and energy consumption at the 10% significance level. Likewise, a significant and positive relationship was found between economic growth and energy consumption at the 95% confidence level. A 1% increase in economic growth will increase energy consumption by about 15%. The constant coefficient value also expresses the significance in the model.

5. DISCUSSION AND CONCLUSION

A long-term causal association between energy and GDP was discovered in the group of Asian nations because of the Lee and Chang (2008) research. It was found by Lee et al. (2008) research that there is a bidirectional link between GDP and energy in the OECD sample. Like this, the findings of the research by Tsani (2010) have shown a unilateral causal connection between Greece's real GDP and total energy usage at aggregate levels. As the research by Altunbas and Kapusuzoglu (2015) shows that there is no cointegration link between GDP and energy usage, there is no long-term relationship between these variables, but instead a short-term causation relationship that is unidirectional. It was found by Kais and Ben Mbarek's research from 2017 that growing and sustainable economic development has an impact on sustainable energy consumption.

Numerous nations are already fulfilling their domestic energy requirements by capitalizing on the advantages offered by renewable energy sources. The impact of energy production, whether from traditional or renewable sources, has a substantial role in the economic development of a nation (Huseynli, 2022c). The economic tools of causation and efficiency are useful for promoting efficient and sustainable energy usage, according to Shahbaz et al. (2018). The findings of the study by Fang and Wolski (2021), which declared the neutrality hypothesis for the collective use of energy and coal, as well as natural gas and hydroelectricity, however, show that human capital is weak and that there is a unilateral causal link from GDP to oil as shown by the results of the nonlinear approach. The linear approach also had an impact and energy. The research by Yilmaz and Cowley (2022) revealed that whereas a 1% rise in trade openness increased electricity consumption by 0.63%, a 1% increase in GDP increased electricity consumption by 0.92%. According to the research done by Bairagi and Ghosh in 2022, however, it was shown that economic growth raises living standards and has a favorable impact on carbon emissions due to power use.

Renewable energy sources are one of the important economic factors of today. Energy resources are of great importance for economic growth. In this study, which measures the importance of energy consumption within the scope of economic growth and renewable energy, the effects of renewable energy sources and economic growth on energy consumption are investigated. In the study, the relationship between renewable energy sources and economic growth and energy consumption was examined by making panel cointegration analysis for Greece between 1997 and 2015. The created model was estimated by the EKK method. Necessary assumptions were tested for the final analysis. According to the empirical findings obtained in the analysis, both renewable energy consumption and economic growth have a significant effect on energy consumption. According to the results of the analysis, the panel data model established is significant at the 95% level. According to the R^2 value, the independent variables explain about 78 percent of the change in the dependent variable. A negative significant relationship was found between renewable energy consumption and energy consumption. A significant and positive relationship was found between economic growth and energy consumption at the 95% confidence level. A 1% increase in economic growth will increase energy consumption by about 15%. This result obtained because of the estimation also supports the theoretical expectation.

Table 2 : White test results

Test statistic	Probability value
5.246267	0.3866

Table 3: Wooldridge's test results

Test statistic	Probability value
20.063	0.0241

Table 4: VIF criteria results

Variable	VIF	1/VIF
Renewable energy output	1.09	0.913872
LGDP	1.09	0.913872
Mean VIF		

Table 5: Least squares estimation test result

R^2	Number of observations	Prob		
0.7801	19	Prob >0.0000		
Energy consumption	**Coefficient Values**	**Resistive Standard Errors**	**T statistics**	**P>|t|**
Renewable energy output	−0.0049263	0.0007943	−6.20	0.000
LGDP	0.1476101	0.0288908	5.11	0.000
Fixed Coefficient	1.787189	0.3236526	5.51	0.000

Renewable energy sources have gained an important place in the national economies today and many countries have started to meet their energy demand with renewable energy sources. Especially developed and developing countries attach more importance to this. With all this, policymakers need to better understand what drives or hinders people's decisions. For this reason, it is recommended to examine the issues related to energy consumption from different perspectives in future studies.

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