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Renewable Energy Use and Energy Productivity: A Panel Data Analysis

Gonca YILMAZ*, Esat DAŞDEMİR*

Abstract

This study emphasizes renewable energy source use's effects on productivity, competitiveness, and growth. The hypothesis of the study was tested with panel data analysis on European and Central Asian countries. Panel data analysis covered 15 Eurasian countries with data from 1990-2014. In our hypothesis, renewable energy use increases income by increasing efficiency in production. The model established reveals the difference between various energy types and renewable energy. Analysis outputs support the study hypothesis. According to the results, the increase in the share of renewable energy use in total energy use affects per capita income positively. On the other hand, an increase in the share of fossil fuels decreases per capita income. Our study suggests that countries aiming for better economic growth should increase their use of renewable energy.

Keywords: *Energy, Renewable Energy, Energy Productivity, Sustainability, Economic Growth*

JEL Codes: *C33, Q01, Q42*

1. Introduction

Energy is a power that we need and use in every field of life, from lighting to warming, from growing industry to technology. The rapid increase in the world population has increased the need for energy and caused our natural resources to be depleted rapidly. Although the world meets 80% of its energy requirement from fossil fuels, it is known that oil and fossil fuels such as oil and coal reserves are limited. Climate change and global warming reduction of fossil fuel reserves increased environmental pollution, and the destruction of nature brought up the issue of alternative energy sources. With the use of renewable energy sources, it is possible to reduce carbon emissions. Renewable resource usage is necessary for a sustainable economy and life. For a life that will maintain ecological balance, resources should also be renewable. Renewable energy sources are briefly as follows; solar, wind, hydroelectric, geothermal, wave, biomass energy, etc.

In recent years, the reality of climate change has brought up the question of how to use energy resources more efficiently.

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* Lecturer, Istanbul Gelisim University, Istanbul, TURKEY, E-mail: goyilmaz@gelisim.edu.tr
https://orcid.org/0000-0002-4763-0742
* Lecturer, Istanbul Gelisim University, Istanbul, TURKEY, E-mail: edasdemir@gelisim.edu.tr
https://orcid.org/0000-0001-8950-2020

Accordingly, discussions on alternative energy sources have increased. Some alternative approaches that respect sustainable understanding are sustainable environment and development, green energy, green economy, natural resources economy, and circular economy. By using energy efficiently at every stage of our lives, we can contribute to the family budget, the country's economy, and the environment's protection without limiting our needs. Countries have several efforts towards the energy transition: changing primary energy consumption, improving energy efficiency and technologies. As a result of all these effects, energy efficiency is an important determinant of global sustainable competitiveness.

This study examines the contribution of renewable energy use to energy productivity, which is one of the main determinants of sustainable competitiveness. And the comparison of the use of renewable energy with other energy types in the context of its impact on energy productivity was tested by panel data analysis. The study reveals the effects of renewable energy usage that are not included in the literature.

2. Literature Review

The rapid increase in energy prices and climate change are vital for energy efficiency. And this has led to the energy productivity concept being brought to the agenda. (Ma et al. 2018). Therefore, Countries that attach importance to global warming and climate change issues prefer clean technologies that are cost-cutting and environmentally friendly (Horbach, 2008). Among the most important areas of global warming, issues are the increase in carbon emission and their relationship with energy consumption and economic growth (Waheed et al.2019). Reducing CO2 emissions to zero levels can prevent global warming increases in the long run horizons (Masson-Delmotte et al. 2018).

European Union’s 2020 target of reducing emissions by 20 % by 2020 and this target is one of their strategies for smart, sustainable, and inclusive growth (European Commission, 2010) and countries need to reduce energy costs for global competition at the same time. In this literature review, the reasons and effects of the implementation of renewable energy policies were investigated. Most researchers have evaluated the effects of renewable energy on growth. Chein and Hu (2007), increased renewable energy has a positive relationship with economic efficiency, and the increased consumption of traditional energy sources reduces economic efficiency. Similarly, Paramati, Sinha, and Dogan (2017) analyzed the relationship between economic growth and renewable energy for the developing from 1991 to 2012. The result of renewable energy has a positive and important relationship with economic growth.

Ozturk and Bilgili (2015), economic growth is positively affected by biomass consumption in African countries. Applying dynamic panel analyses for 51 Sub-Sahara African countries for the 1980–2009 period. The governments of Thailand, Mexico, and South Africa have successfully implemented renewable energy programs, reducing their economy's dependence on fossil fuels. South Africa and Thailand are some of the renewable energy sources, about 5% of the total electricity supply. Mexico adds 13.6% of its renewable energy sources to the electricity mix (Rennkamp et al. 2017). Ay (2021) also revealed that environmental pollution has a significant impact on economic efficiency.

The type of energy used as input is an important determinant of productivity and productivity is the most important determinant of global competitiveness (Dasdemir, 2018). Therefore, the environmental approach, productivity, and competitiveness are like a chain that is interconnected. Considering the studies as a global competitive advantage; China has developed rapidly in the field of wind power equipment manufacturing. The total market share of the world's top ten wind turbine manufacturers in 2018 was 29.32% (Huang, 2020).

Countries have also started to take important steps within the scope of returning to renewable energy. Especially some developed countries show their intention to lead this transformation. The German government has announced that it will eliminate nuclear power generation and replace it with renewable energy within 10 years, reduce greenhouse gas emissions by 40% and 80% by 2020, and renewable energies would contribute 80% of German energy by 2050 (Park et al. 2016).

Studies are comparing renewable energy and other energy types in the literature. In the period 1960-2007, the causal relationship between renewable and nuclear energy consumption, CO_2 emissions, and real GDP for the USA was investigated. According to the results of the study, there is a one-way causality that extends from nuclear energy consumption to CO_2 emissions (Menyah and Rufael, 2010).

Fossil energy technologies negatively affect the environment more than renewable energy technologies. And provide energy security by reducing energy dependence. Activities that use technological infrastructure together with the Information Age create a global value chain (Cetin and Yilmaz, 2017). This reveals the importance of technological investment. Saidi and Omri (2020) show that investment in nuclear energy and renewable energy reduced CO_2 emissions in the USA, Sweden, Canada, UK, Belgium, Finland, Czech Republic, France, Germany, Japan, Switzerland, and renewable and nuclear energy consumption CO_2 emissions for the panel estimations.

3. Model and Analysis

The hypothesis proposed within the scope of the study was tested with panel data analysis. 15 Eurasia countries producing nuclear energy between 1990 and 2014 selected for analysis. The data used in the analysis are taken from the World Bank (WB) database. The definitions of the variables are given in Table 1.

Table 1 Variable Name and Definition

Variable Name	Definition
GE	GDP per unit of energy use (constant 2017 PPP $ per kg of oil equivalent)
REC	Renewable energy consumption (% of total final energy consumption)
EPC	Electricity production from coal sources (% of total)
EPH	Electricity production from hydroelectric sources (% of total)
EPO	Electricity production from oil sources (% of total)
EPG	Electricity production from natural gas sources (% of total)
EPAN	Alternative and nuclear energy (% of total energy use)
EPN	Electricity production from nuclear sources (% of total)
GCF	Gross capital formation (% of GDP)

The model and its economic form calculated in the study are as in given equations 1 and 2 at below.

$$lGE = f(lREC, lEPC, lEPH, lEPO, lEPG, lEPAN, lEPN, lGCF) \quad (1)$$

$$lGE_{it} = \beta_0 + \beta_1 lREC_{it} + \beta_2 lEPC_{it} + \beta_3 lEPH_{it} + \beta_4 lEPO_{it} + \beta_5 lEPG_{it} + \beta_6 lEPAN_{it} + \beta_7 lEPN_{it} + \beta_8 lGCF_{it} + \varepsilon_{it} \quad (2)$$

The analysis reveals the impact of renewable energy and various other energy types on energy productivity. The share of gross capital formation in GDP is used as the control variable and is expected to be positive with the GE variable. In the model, "i" refers to the unit and "t" refers to the time dimension. "ε_{it}" is the error term "β_0" is the constant-coefficient and the symbols before the variables are the coefficient of that variable.

For all tests for the validity of the predictions and predictions Stata 16 Package Program used. The letter "l" in front of the variables indicates that the logarithm of the variable is taken. The logarithm of the variables taken with the Stata 16 Package Program.

In panel data analysis, the model needs to be tested for the existence of unit and/or time effects. The econometric model changes according to the existence of the unit and/or time effect. The results of F, LM and LR tests regarding the existence of unit and time effects are given in Table 2.

Table 2 Unit and Time Effects Tests

Effect	Test	P Value	Result
Unite	F Test	0.000	Null Hypothesis Reject: Unit Effect Exist
	LM Test	0.000	
	LR Test	0.000	
Time	F Test	0.0245	Null Hypothesis Reject: Time Effect Exist
	LM Test	0.9200	Null Hypothesis Can’t Reject: Time Effect Doesn’t Exist
	LR Test	1.000	

As can be seen from the table, there are unit effects according to F, Lagrangian Multiplier (LM) and Likelihood Ratio (LR) tests. However, time effects are found with a 5% margin of error according to F test, but not according to LM and LR tests. According to results obtained from the LM and LR tests it is decided that there are unit effects in the model but not time effects. The model with unit effects is shown in the form at equation 3.

$$lGE_{it} = \beta_0 + \beta_1 lREC_{it} + \beta_2 lEPC_{it} + \beta_3 lEPH_{it} + \beta_4 lEPO_{it} + \beta_5 lEPG_{it} + \beta_6 lEPAN_{it} + \beta_7 lEPN_{it} + \beta_8 lGCF_{it} + \varepsilon_{it} \quad (3)$$

Unit effects refer to the presence of separate coefficients for each unit. This situation is shown economically in equation 3. The model expressing unit effects can also be shown in the figure in equation 4.

$$lGE_{it} = \beta_0 + \beta_1 lREC_{it} + \beta_2 lEPC_{it} + \beta_3 lEPH_{it} + \beta_4 lEPO_{it} + \beta_5 lEPG_{it} + \beta_6 lEPAN_{it} + \beta_7 lEPN_{it} + \beta_8 lGCF_{it} + \mu_i + \varepsilon_{it} \quad (4)$$

"μ_i" in Equation 4 refers to the unit effects arising from the characteristic feature for each “i” unit. One of the method of fixed or random effects should be chosen based on whether the explanatory variables are associated with the value of "μ_i" expressing the unit effect. In case the unit effect correlates with explanatory variables, fixed effects (FE) methods can be used. If there is no correlation relation, one of the random effects (RE) methods should be chosen. Although there is no correlation relationship, selecting fixed effects may exclude important information coming from unit effects from the model.

Hausman (1978) Test performed for the determination of the FE or RE methods to choose. For this purpose, Hausman and Robust Hausman tests were carried out. The null hypothesis in two Hausman tests is RE methods are not efficient. P-value for the Hausman test is 0.9994 and 1.0000 for the Robust Hausman test. Both test results show that the RE method is valid and effective. Therefore, estimates made with RE models are safer.

Accordingly, RE models were used to explain the relationship between variables.

The assumption deviation tests for the RE method are given in Table 3.

Table 3 Assumption Deviation Tests for RE Method

Test		P Value (Stat)	Result
Normality	Skewness and Kurtosis (Unit Effect)	0.4296	Null Hypothesis Can't Reject: Error Terms and Unit Effect are Normal
	Skewness and Kurtosis (Error Term)	0.9072	
Heteroscedasticity	Levene	0.000	Null Hypothesis Rejected: Error Terms are Heteroscedastic
	Brown	0.000	
	Forsythe	0.000	
Autocorrelation	Durbin-Watson	(0.392)	Null Hypothesis Rejected: Autocorrelation Does Exists
	Baltagi-Wu LBI	(0.263)	
Intertemporal Correlation	Pesaran	0.158	Null Hypothesis Can't Reject: Intertemporal Correlation Doesn't Exists
	Friedman	0.002	Null Hypothesis Rejected: Intertemporal Correlation Does Exists
	Frees	(2.258)	
Multicollinearity (Mean Variance Inflation Factor)		7.81	No Multicollinearity

Skewness and Kurtosis test was performed to test the normal distribution. Levene (1960), Brown and Forsythe (1974) tests performed to detect the heteroscedasticity problem. Durbin-Watson (1971) and Baltagi-Wu, (1999) LBI tests were performed to detect the autocorrelation problem. And Pesaran (2004), Friedman (1937), and Frees (2004) tests were performed to detect the intertemporal correlation problem. According to variance inflation factor (VIF) value is less than 10 there is no multicollinearity problem.

The results given in the table show that the predicted model has heteroscedasticity, autocorrelation and intertemporal correlation problems. Therefore, the Driscoll-Kraay (1998) Standard Errors (DKSE) method is suitable for predicting the model. Predicted models and significance levels are given in Table 4.

Table 4: Predicted Outputs: Dependent Variable GE

Regression Method		LREC	LEPC	LEPH	LEPO	LEPG	LEPAN	LEPN	LGCF	Constant	R-Squared
Pooled OLS		0.073**	0.067*	-0.199*	0.027***	0.012	1.007*	-0.837*	-0.001	2.020*	0.449*
Robust Pooled OLS		0.073*	0.066*	-0.199*	0.027**	0.012	1.00*	-0.837*	-0.001	2.020*	0.461*
Between Regression		0.073**	0.066*	-0.199*	0.027***	0.012	1.007*	-0.837*	-0.001	2.020*	0.461*
Robust Between Regression		0.073*	0.066*	-0.199*	0.027***	0.012	1.007*	-0.837*	-0.001	2.020*	0.461*
First Difference^		0.058*	-0.121*	-0.120*	-0.118*	-0.111*	0.070*	-0.141*	.017*	…	0.280*
Fixed Effect	Least Squares Shadowing sensitivity	0.145*	-0.044***	-0.034	-0.081*	-0.009	0.247*	-0.139**	0.006*	1.754*	0.941*
	Robust Least Squares Shadowing sensitivity	0.145*	-0.044***	-0.034	-0.081*	-0.009	0.247*	-0.139**	0.006*	1.754*	0.941*
	Within Regression	0.145*	-0.044**	-0.034	-0.081*	-0.009	0.247*	-0.139**	0.006*	1.614*	0.704*
	Robust Within Regression	0.145**	-0.044	-0.034	-0.081*	-0.009	0.247	-0.139	0.006*	1.614*	0.704*
Random Effect	Within Regression	0.148*	-0.035	-0.064**	-0.084*	-0.009	0.235*	-0.142**	0.006*	1.684*	0.138*
	Robust Within Regression	0.148*	-0.035	-0.064	-0.084*	-0.009	0.235	-0.142	0.006*	1.684*	0.138*
	Generalized Least Squares	0.073*	0.067*	-0.199*	0.027***	0.012	1.008*	-0.837*	-0.001	2.021*	…*
	Maximum Likelihood Estimator	0.147*	-0.037	-0.058**	-0.083*	-0.009	0.237*	-0.142**	0.006*	1.668*	…*
	Population-Averaged	0.147*	-0.037	-0.058**	-0.083*	-0.009	0.237*	-0.142**	0.006*	1.668*	…*
	Robust Population-Averaged	0.147**	-0.037	-0.058	-0.083*	-0.009	0.237	-0.142	0.006*	1.668*	…*
DKSE	Pooled OLS	0.073**	0.067*	-0.199*	0.027***	0.012	1.007*	-0.837*	-0.001	2.020*	0.461*
	Fixed Effect	0.145*	-.044***	-.0342	-.081*	-.009	.247*	-.139**	.006**	1.615*	0.705*
	Random Effect	0.148*	-0.035*	-0.064	-0.084*	-0.009	0.235*	-0.142*	0.005**	1.683*	0.138*

*: p<%1, **: p<%5, ***: p<%10

^: variable not logarithmic

According to the results of the Hausman test and assumption deviation tests, the Driscoll-Kraay random effects model is more suitable to be interpreted instead of other estimates given in Table 4. According to the estimation results, 1% increase in the share of renewable energy consumption in total energy consumption, GDP per unit energy consumption increases by approximately 0.15%. 1% increase in the share of electricity production from coal sources in total electricity production, GDP per unit energy consumption decreases by approximately 0.04%. 1% increase in the share of electricity production from hydroelectric sources in total electricity production, GDP per unit energy consumption decreases by approximately 0.06%, but not significant. 1% increase in the share of electricity production from oil sources in total electricity production, GDP per unit energy consumption decreases by approximately 0.08%. 1% increase in the share of electricity production from natural gas sources in total electricity production, GDP per unit energy consumption decreases by approximately 0.01%, but not significant. 1% increase in the share of alternative and nuclear energy in total energy use, GDP per unit energy consumption increases by approximately 0.24%. 1% increase in the share of electricity production from nuclear sources in total electricity production, GDP per unit energy consumption decreases by approximately 0.14%. 1% increase in the share of gross capital formation in GDP, GDP per unit energy consumption increases by approximately 0.01%.

4. Concluding Remark and Policy Suggestions

Orientation towards alternative energy sources comes to the fore as a necessity rather than a choice. The negative outcomes arising from climate change and global warming have shown us the necessity of reconsidering resource efficiency. Destroying nature and reducing fossil fuel reserves brought new alternative approaches. Green economy, circular economy, natural resources economy, green energy are some of these alternative approaches. Among the most important areas of global warming, issues are the increase in carbon emission and their relationship with energy consumption and economic growth. The main purpose of our study is how to use natural resources and resources efficiently. We see the importance of renewable energy and other energies that are handled within the framework of sustainable development and sustainable competitiveness in the economic field.

Particularly, countries that stand out with their competitive attitudes in global markets have positive attitudes towards alternative energies. Efficiency is one of the key factors for countries to achieve better sustainable competitiveness. In this context, the efficiency of energy, which is the most important input of production, has become a tool for countries aiming to increase their sustainable competitiveness.

The study argues that renewable energy will provide a more efficient form of production, thus increasing the competitiveness of the country. The study hypothesis was tested by panel data analysis. Panel data analysis gave similar results to the studies in the literature. As a result of the test, a positive relationship has been found between renewable energy consumption and energy productivity. The increase in energy types other than renewable and nuclear energy negatively affects energy productivity.

This study revealed that countries should increase their renewable energy use to increase their sustainable competitiveness. Countries should invest in renewable energy; It should shape their physical and human capital accordingly. Policymakers need to see the use of renewable energy not only from an environmental perspective but also as an economically beneficial tool.

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