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THE IMPACT OF RENEWABLE ENERGY ON GDP

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ABSTRACT

Besides traditional production factors, such as labor and capital, one of the inputs used in the production process is energy. Although the use of fossil fuels is more common in many production processes renewable energy sources are increasingly important in ensuring sustainable development. In many countries in the world, the share of renewable energy is the total energy consumption is very high, including in European Union (EU) countries. The purpose of this study is the investigate the output elasticity coefficients of capital and renewable energy in 12 EU countries by using the Cobb–Douglas production function approach. In this study, the Gross domestic Product these countries from 2000 to 2017, was examined using a generalized method of moments estimation, which used labor, capital, and renewable energy data. As a result of the study, the output elasticity coefficient in the Cobb–Douglas production function was found to be 1.147. This indicates that a 1% increase in labor, capital, and renewable energy increased GDP by 0.598%, 0.446%, and 0.093%, respectively. Among the findings, the relationship between GDP and explanatory variables is statistically significant and economically significant. It is understood that there is a positive relationship between the variables.

Contribution/Originality: This study contributes to existing literature by investigating the output elasticity coefficients of capital and renewable energy using the Cobb–Douglas production function approach.

1. INTRODUCTION

Along with traditional production factors such as labor and capital, energy is one of the indispensable inputs of production. Fossil fuels, such as oil, natural gas, and coal, are widely used in production processes. However, the use of renewable energy sources has become increasingly widespread in order to ensure energy supply security and to protect the environment based on sustainable development. Today, the share of renewable energy of the total energy consumption is continuously increasing in EU countries. These countries, which do not have sufficient oil, gas, or coal resources, import the energy that they need. Therefore, EU countries have become foreign-dependent on energy, and various energy policies have been established in order to reduce this dependency. Today, the scope of the EU's energy policies can be listed as ensuring effective energy consumption, seeking alternative energy sources, and increasing the production of new and renewable energy sources.

The inputs used in production have an impact on the output. In economic theory, the effect of inputs on the outputs is explained by the concept of output flexibility. Output flexibility is defined as the sensitivity of production to the proportional changes that occur to the inputs used in production and the coefficients are equal to the total and show the return according to the scale (Kurumu, 2011).

The relationship between GDP and energy consumption has attracted the attention of many economists. In literature from various countries around the world, numerous studies have been carried out in EU However, the common features of these studies are the long-term causality relationships between energy sources and economic growth. As explained in the literature review, the results of these studies indicated that the two parameters mentioned had the right or opposite relationships with each other. The conclusion drawn from the examination of these studies on the analysis of the impact of the change in inputs on the outputs was that the work was inadequate.

In countries that are dependent on foreign energy, the trend towards renewable energy sources is quite high. In production processes, renewable energy use has become as important as labor and capital. The purpose of this study is the investigate the output elasticity coefficients of capital and renewable energy in 12 EU countries by using the Cobb–Douglas production function approach. In this study, the Gross domestic Product these countries from 2000 to 2017, was examined using a generalized method of moments estimation, which used labor, capital, and renewable energy data.

In the first section, renewable energy sources and policies of the EU are mentioned; in the second section, empirical studies examining the relations between GDP, labor, capital, and renewable energy are included; in the third section, econometrics with the dataset used in the analysis methodology are introduced; the fourth section shows the results of the econometric analysis; and the final section comprises the conclusion and policy suggestions based on the results.

2. RENEWABLE ENERGY SOURCES IN EUROPEAN UNION COUNTRIES

The main objective of energy policies is to ensure sustainability. Environmental protection to ensure energy sustainability and combat climate change is constantly being observed. One of the most important steps in this regard was taken in 2007 with the decision of the energy and climate change package led by the European Commission. The 2020 energy strategy, published in 2010, set out three important energy-related targets to reach the reduce greenhouse gas emissions by at least 20% compared to 1990, increase the share of renewable energy sources of the total energy supply to 20%, and increase the share of renewable energy used in vehicles to 10%. The overall aim is to save 20% in primary energy resource consumption (European commission, 2019a; TR Ministry of Foreign Affairs, 2017). These targets were revised in 2014 and are due to be reviewed again in 2030. The energy strategy for the year was announced, and according to this strategy, renewable energy increased its share in the total energy consumption to 27%. It aims to reduce greenhouse gas emissions by 40% and increase energy efficiency to 27% (Bonn, Heitmann, Reichert, & Voßwinkel, 2015). In addition, 2030 targets were revised in 2018, and the decision was made to increase the share of renewable energy to 32% and effective energy consumption to 32.5% (European commission, 2019a). Production and consumption of renewable energy are the main energy policies of the EU, and the provision is based on contributing to the protection of the environment based on competition and sustainable development (European Commission, 2019bc).

The common energy policy of all member states could not be established across the EU. The European Commission, therefore, seeks to harmonize the goals of each member country to increase the share of renewable energy use of their total energy consumption. The obligation to calculate the consumption of these resources according to GDP was requested from the member countries. Accordingly, priority was given to environmental protection to ensure sustainable development in EU countries. Elements related to the green economy, such as environmental protection, resource efficiency, social integration, and creating new business areas are integrated into various EU policies (Yılmaz, 2014) and are the main aspects regarding renewable energy sources in the EU.

Each country in the EU has different energy consumption patterns according to its economic growth rate and economic structure. Table 1 shows the data of 12 selected countries with high renewable energy production capacity in the EU.

Table 1. Total renewable energy resource production capacity (MW).

	2010	2011	2012	2013	2014	2015	2016	2017	2018
EU Country	322 521	361 475	395 655	420 261	440 680	465 132	489 206	513 360	536 719
Germany	56 546	67 424	78 164	83 766	90 320	98 013	104 746	112 719	119 388
Italy	29 507	40 822	46 721	48 857	49 526	50 417	51 195	52 128	53 290
France	31 717	34 903	37 126	38 773	40 424	42 759	44 921	47 972	50 504
Sweden	22 707	23 469	24 293	24 645	25 528	26 869	27 805	28 337	29 178
Spain	42 246	43 920	46 413	47 676	47 711	47 742	47 776	47 899	48 277
England	9 627	12 783	15 902	20 027	24 895	30 822	35 488	40 311	43 460
Finland	5 127	5 282	5 329	5 632	5 863	6 256	6 858	7 618	7 867
Austria	44 980	44 980	40 866	51 210	50 410	49 977	47 369	50 922	50 854
Poland	2 178	3 019	4 094	5 116	5 638	6 919	7 881	7 982	8 236
Romania	6 791	7 410	8 354	10 098	11 152	11 212	11 162	11 145	11 148
Netherlands	3 562	3 748	4 038	4 547	4 837	5 808	7 185	7 942	9 753
Portugal	9 607	10 548	10 955	11 143	11 573	12 153	13 208	13 541	13 787

Source: IRENA (2019).

As seen in Table 1, the capacity related to these resources increased from 3.2 GW to 5.4 GW between 2010 and 2018 thanks to technological progress throughout the EU. The highest capacity increases in this period were realized by Poland, England, Holland, Germany, Italy, and France, respectively. With the increase in capacity across the EU, renewable energy production has increased economically. In addition, the fact that Germany has approximately 20% of the total capacity indicates that this country has an important share in the production of renewable energy. The relationship between renewable energy use and economic growth is no different from the relationship between general energy consumption and economic growth.

3. LITERATURE REVIEW

Studies that investigated the causality relationship between renewable energy and economic growth, as well as studies that analyzed flexibility coefficients in a production function, are summarized below.

In a study by Sari and Soytas (2007), an analysis was made within the scope of the Cobb–Douglas production function using labor, capital, and energy inputs from ten countries between 1971 and 2002. As a result of this study using VAR analysis, it was determined that energy may be a more important input than labor and capital in some countries. However, Sadorsky (2009) in this study, general renewable energy data was used a cointegration analysis to examine the relationship between renewable energy consumption and per capita income in developing countries. The results showed an increase in real income per capita, which increased renewable energy consumption per capita in the long term. The relationship between economic growth and renewable energy sources was studied by differentiating the period and country using renewable energy, GDP, labor, and fixed capital formation variables (Apergis & Payne, 2010a, 2010b, 2011a, 2011b, 2012). In their studies, panel cointegration and panel causality were investigated, and a two-way causality relationship was found between Renewable energy consumption and GDP. Menegaki (2011) investigated the relationship between economic growth and renewable energy sources in 27 EU countries from 1997 to 2007. As a result of the study conducted in the framework of multivariate panel data, it was determined that there was no causal relationship between the two variables.

Ocal and Aslan (2013) examined relations between renewable energy consumption and economic growth in Turkey from 1990 to 2010. This study used the Toda–Yamamoto and ARDL causality tests; it was found that there is an inverse relationship between renewable energy consumption and economic growth and that economic growth affects renewable energy consumption. Apergis and Dănuleţiu (2014) investigated the relationship between renewable energy and economic growth in 80 developed and developing countries. The study used the panel data analysis method, and the Canning–Pedroni causality test was applied using data from 1990 to 2012. It was determined that a causality relationship exists between economic growth and renewable energy consumption.

Kula (2014) examined the relationship between economic growth and renewable energy per capita using the dynamic panel data method in 19 OECD countries from 1980 to 2008, and a causality relationship between economic growth and renewable energy consumption was found. In studies by Salim, Hassan, and Shafiei (2014), the relationships between energy sources, industrial sector production, and economic growth in 29 OECD countries between 1980 and 2011 were analyzed. In studies that used Westerlund cointegration and panel Granger causality analysis, it was found that there was a bidirectional causality relationship between the variables in the long term. In studies by Çermikli and Tokatlıoğlu (2015), the Cobb–Douglas production function, which used labor, capital, and energy inputs for 44 countries (27 high-income and 17 middle-income) was estimated between 1990 and 2011. In this study, the effect of development in different technologies on energy intensity was investigated. As a result of the study using the panel data analysis method, it was found that energy savings of 1.25% in high-income countries and 1.65% in middle-income countries were achieved due to advances in technology.

In the works of Shahbaz, Loganathan, Zeshan, and Zaman (2015), the relationship between renewable energy and economic growth in Pakistan was examined for the period between January 1972 to April 2011.In the study in which the ARDL method and vector error correction model were used, it was concluded that the variables cointegrated in the long term, the use of renewable energy increases economic growth, and there is a bidirectional causality relationship between the variables. In studies by Aslan and Ocal (2016), the relationship between renewable energy use, capital and labor, and economic growth in countries that were new to the EU between 1990 and 2009 was investigated. As a result of the study using the ARDL and Hatemi-J causality tests, it was found that there is a one-way effect from renewable energy use to economic growth in the countries included in the study. In studies by Bhattacharya, Paramati, Ozturk, and Bhattacharya (2016), the relationship between renewable energy consumption and economic growth was investigated in 38 countries with the most renewable energy resources in the world from 1991 to 2012. In the study that used the Pedroni panel cointegration test, panel dynamic ordinary least square (DOLS) estimation and panel Granger causality test, renewable energy is economical, and it was concluded that it has a positive effect on growth. Dogan (2016) studied data from 1988 to 2012 on economic growth and energy consumption in Turkey. As a result of the study, which used the ARDL method, and the Johansen and Gregory–Hansen cointegration tests, the use of fossil fuel energy was determined to have a positive effect on economic growth, but that renewable energy does not affect economic growth.

To support research by Aslan and Ocal (2016), the relationship between non-renewable and renewable energy consumption and economic growth was investigated in 17 emerging market economies between 1980 and 2012. The study used a panel causality test, and the results showed a one-way relationship from economic growth to renewable energy consumption in Colombia and Thailand, a one-way relationship from renewable energy consumption to economic growth in Peru, and a mutual causality relationship between renewable energy and economic growth in Greece and South Korea. It was determined that there was no relationship between the variables in other countries. Ito (2017) investigated the relationship between energy consumption and economic growth in 42 developing countries between 2002 and 2011. As a result of using the generalized moment method (GMM), renewable energy consumption in the long term was found to positively affect economic growth. In studies by Kahia, Ben Aissa, and Charfeddine (2017), the relationship between non-renewable and renewable energy consumption and economic growth in the oil-importing MENA countries from 1980 to 2012 was investigated. The study used a panel data analysis and the results showed a bidirectional causality relationship between renewable energy consumption and economic growth. In studies by Koçak and Şarkgüneşï (2017), the relationship between renewable energy and economic growth was investigated in nine Black Sea and Balkan countries from 1990 to 2012. The results of the study using panel data analysis indicated that there is a long-term and right-way relationship between renewable energy and economic growth. Rafindadi and Ozturk (2017) investigated the relationship between renewable energy and economic growth in Germany from January 1970 to April 2013. The study used the ARDL boundary test and Bayer–Hanck cointegration test, and it was determined that renewable energy consumption increased economic growth, and a two-way causality relationship exists between the variables.

Bulut and Muratoglu (2018) investigated the relationship between renewable energy and economic growth in Turkey from 1990 to 2015, and the result of these studies, which were carried out using the ARDL and Khatami–Jan causality tests, indicated economic growth in Turkey.

It has been found that there is no causal relationship between renewable energy and Economic growth Durgün and Durgün (2018) investigated relations between GDP per capita and renewable energy consumption per capita in Turkey from 1980 to 2015. The study was conducted using the ARDL boundary test and cointegrated Toda–Yamamoto causality test, and a one-way causality relationship was found from renewable energy use to economic growth. Alper and Oguz (2016), investigated economic growth and renewable energy relations in Turkey between 1990 and 2017. The study used the Bayer–Hanck cointegration test and the Toda–Yamamoto causality test, and it was determined that there is a one-way causality relationship between variables in the long term from economic growth to renewable energy consumption.

In the study by Marinaş, Dinu, Socol, and Socol (2018), the relationship between economic growth and renewable energy sources in central and eastern Europe was investigated from 1990 to 2014. The results of the study using the ARDL method, both short and long term, determined that there was a significant relationship between the variables. Stamatios et al. (2018) found a positive relationship between economic growth and consumption of renewable energy and other energy in 25 EU member states from 2007 to 2016. Songur (2019) studied GDP in Turkey from 1982 to 2014 using labor, capital, natural gas, oil, and coal translog production function estimated data. In the study conducted using the Ridge regression method, it was found that the elasticity of substitution between inputs remained at same level, while the output elasticities were positive.

Many studies have been conducted to investigate the relationship between renewable energy consumption and economic growth, and to examine the relationship between output and labor, capital, and energy within the scope of the production function. However, due to the different methods used, the selected sample group, the time intervals examined, and the different data sets, a common conclusion regarding the causality relationships could not be reached. Unlike the studies summarized above, the differences between the countries and the variables considered in this study, as well as the output elasticity coefficients of GDP and variables of labor, capital, and renewable energy are calculated within the scope of the Cobb–Douglas production function. The work carried out is detailed below.

4. METHODOLOGY

4.1. Data Set

Data on GDP, labor (L), capital (K) and renewable energy (RE) from 2000 to 2017 in 12 EU countries with the largest share in the production of renewable energy based on the flexibility of renewable energy, labor, and capital inputs were used. The countries used as examples were Germany, Italy, France, Sweden, Spain, England, Finland, Austria, Poland, Romania, the Netherlands, and Portugal. The definitions and data sources of the variables used in the analysis are given in Table 2.

Table 2. Definitions of variables and data sources.

Variables	Description	Source
GSYH	2011 prices (in millions of dollars)	Penn World Table, PWT 9.0
L	Million people	Penn World Table, PWT 9.0
K	Gross fixed at prices in 2011 capital formation (in millions of dollars)	World Bank
RE	Renewable energy sources, including biofuels	Eurostat

4.2. Cobb–Douglas Production Function

In order to show the relationship between inputs and outputs, and to obtain the flexibility coefficient of the production and the output elasticity coefficient according to the inputs, the Cobb–Douglas production function was used. The Cobb–Douglas production function was developed in 1928 by Charles Cobb and Paul Douglas. This production function helps to calculate the flexibility of production for labor and capital, and the flexibility of production for renewable energy. By adding GDP as a dependent variable to be estimated in the Cobb–Douglas production function, labor, capital, and renewable energy were used as independent variables. Therefore, the below three-input Cobb–Douglas production function is created:

$$GSYH = AK^{\alpha}L^{\beta}RE^{\delta} \qquad (1)$$

In order to express equation 1 in linear form, the natural logarithm of both sides of the equation was taken and arranged in equation 2. Since the growth rate in the period being studied (t-1) affects the overall growth rate (t) the Cobb–Douglas production function utilized a dynamic panel data analysis. In this context, the Cobb–Douglas production function converted to linear form is shown below.

$$LnGSYHit = \alpha LnKit + \beta LnLit + \delta LnREit + \theta LnGSYHi, t-1 + \mu i + \lambda t + uit \qquad (2)$$

The parameters to be estimated in this analysis are α, β, δ, and θ. In the dynamic panel data analysis, μi shows the unit effect, λt shows the time effect, and uit is the error term of the equation. In equation 2, ($e_K = \alpha$) is the elasticity coefficient of production to the K factor, ($e_L = \beta$) is the flexibility coefficient of production to the L factor, and ($e_{RE} = \delta$) is the flexibility coefficient of production of the renewable energy input. The sum of these flexibility coefficients gives the output elasticity coefficient. As stated earlier, output flexibility is defined as the proportional change created in production by a proportional change in inputs. The flexibility of production inputs can also be calculated as the ratio of the marginal product of the input to the average product. These flexibility coefficients are given below.

$$e_K = \frac{MP_K}{AP_K} \qquad (3)$$

$$e_L = \frac{MP_L}{AP_L} \qquad (4)$$

$$e_{RE} = \frac{MP_{RE}}{AP_{RE}} \qquad (5)$$

Output flexibility is equal to the sum of these three flexibility coefficients.

$$e_K + e_L + e_{RE} = e \qquad (6)$$

In equations 3-5, the ratio of marginal product (MP) to average product (AP) gives the flexibility of production for the relevant input. This flexibility will be greater than one if MP > AP, less than one if MP < AP, and one if MP = AP. It also means that in the case of MP < AP, it is in the second region of production.

5. METHOD AND EMPIRICAL FINDINGS

In the first part of the study, the cross-sectional dependence from the dynamic panel data analysis was tested. Horizontal cross-sectional dependence and spatial propagation effects excluded observed or common factors, which may be caused by independence in the error term, and may also arise if these factors are taken into account

(Breitung & Pesaran, 2005). In order to avoid deviated results or false inferences, horizontal cross-sectional dependency should be investigated in the panel data analysis (Chudik, Pesaran, & Tosetti, 2011; Pesaran, 2004).

Chudik and Pesaran (2013) assumed that cross-sectional dependence is often used in panel data analyses and they made parameter estimates. One of the main issues encountered in estimating the model is whether a horizontal cross-sectional dependence exists. Therefore, the cross-sectional dependency was tested initially, assuming that the 12 countries being examined would affect each other. Based on the assumption that there is a variance problem in the dynamic panel data analysis, and that the model has a constant effect, it is not necessary to make preliminary estimates on these issues. In his research, Hoechle (2007) proposed Pesaran's cross-sectional dependent estimation method for models with variable variance (variable error term hypothesis and heteroscedastic variance) and fixed-effect models because of the possible dependency issue between units of data (De Hoyos & Sarafidis, 2006). Results related to this test are given in Table 3.

Table 3. Pesaran's cross-sectional dependency test results.

LogGSYH	Coefficient	Standard Error	t-statistic	P-Value	Confidence Interval 95 %	
LogL	-0.062962	0.0627163	-1	0.317**	0.186628	0.060705
LogK	0.433462	0.0182117	23.8	0.000**	0.397552	0.469373
LogRE	0.136527	0.0093599	14.59	0.000**	0.118071	0.154983
sigma_u	0.264191					
sigma_e	0.017847					
rho	0.995457	(fraction of variance due to u_i)				
F(11, 201)	44.62	F test that all u_i=0				
F(3, 201)	359.11					
R Kare	0.8063					
Prob>f	0.000*					
Pr				**0.0316**		
Pesaran's test of cross-sectional independence				2.149		
Average absolute value of the off-diagonal elements				0.577		
Fixed effects (regression - within)						

Note: *The probability value being zero indicates that the null hypothesis is rejected. In other words, there is a dependency between the size of the cross-sectional units of capital and renewable energy production. ** Since the P value for labor is higher than zero, the null hypothesis is accepted. In other words, there is no cross-sectional dependence between the units of labor datasets. There is a cross-sectional dependence between the units of the other two variables.

As shown in Table 3, Pesaran's cross-sectional dependency test was performed for all logarithmic variables. At the end of this test, except for the labor parameter, the variables with a P value were lower than the error term. Therefore, it was determined that the model demonstrated cross-sectional dependence. After the horizontal cross-sectional dependency test, a unit root test was performed to test the stability of the data sets. There are two types of panel unit root tests in the literature. In the first type, the individual time series in the panel are considered to be distributed cross-sectionally independently (Choi, 2001; Im, Pesaran, & Shin, 2003; Maddala & Wu, 1999), and in the second type, horizontal cross-sectional dependence is permitted (Moon & Perron, 2004; Pesaran, Smith, & Yamagata, 2013).

Since the model has a horizontal cross-sectional dependence, in many studies it is recommended to use the second-generation test method to perform unit root testing. In the study, the unit root test subject was tested using the horizontal cross-sectional Dickey–Fuller (cross-sectionally augmented Dickey–Fuller or CADF) test. In this study, Dickey–Fuller regressions were expanded by taking the first and second differences of the cross-sectional units and the horizontal cross-sectional averages of the lagged values, however, cross-sectional dependence and variable variance problems were found. The most appropriate unit root test was the estimation method by Pesaran (2007), so this method was used in the model as it was developed based on both cross-sectional dependence and variable variance assumption (Lewandowski, 2007). Pesaran’s CADF testing is also recommended for heterogeneous models, including macro panels and time series for 20- to 30-year periods. Within the scope of this test, the exact stationarity of the variables was tested, and the variables with unit roots should be made stationarity. The results of the test are detailed in Table 4.

Table 4. CADF unit root test.

Variables	P-Value	t-bar	cv10	cv5	cv1	z[t-bar]
Log RE	0.090*	-2.668	-2.67	-2.78	-3.01	-1.343*
D1.LogRE	0.000**					
D2.LogRE	0.000***					
LogK	0.167*	-2.559	-2.67	-2.78	-3.01	-0.965*
D1.LogK	0.021**					
D2.LogK	0.000***					
LogGSYH	0.164*	-2.563	-2.67	-2.78	-3.01	-0.979*
D1.LogGSYH	0.366**					
D2.LogGSYH	0.000***					
LogL	0.158*	-2.569	-2.67	-2.66	-3.01	-1.002*
D1.LogL	0.245**					
D2.LogL	0.000***					

Note: * Both P-values and z-bar values indicate that the null hypothesis is rejected. This result shows that logarithm variables contain unit roots. ** Stationarity efforts were made by taking the first difference of the series, however, not all of the series have been made stationary. *** By taking the second difference of the series, the stagnation process was realized in all series.

According to the CADF test results in Table 4, when only the second differences were taken for all series, the null hypothesis was strongly rejected at a 1% probability level. In other words, the related series became stationary in the second difference. Since all the variables could not be made stationary after the first difference of the series was taken, the second difference was taken and a stabilization process of all variables was carried out. In other words, the series are integrated in the second order. Therefore, based on the panel unit root test findings, it was concluded that all the variables subjected to the analysis were integrated in the second order I (2). As a result, considering the cross-sectional dependency in the model, variables were stabilized in the second order by the Pesaran CADF test on logarithm variables.

To select the appropriate final estimation method in the dynamic panel models, the two most important assumptions in the series must be tested. The first test is to determine if the explanatory variables are completely external (internality problem test; the correlation between the error term and the lagged variables), and the second is to test whether the error terms are autocorrelated or not. Anderson and Hsiao (1982) tried to solve this problem by using the tool variables method in their research to solve the problem of internality in the series. In this context, the effect resulting from the correlation between the error term and delayed variables can be kept under control. It should determine whether there is autocorrelation in the error terms in order to solve the problem of internality. However, this test method does not include autocorrelation in the model, and it is assumed that it was not preferred in the final parameter estimation. The results related to the internality problem test conducted in the context of the tool variable method are given in Table 5.

Table 5. Internality test results.

D2.LogGSYH	Coefficients	Standard Errors	Z-Value	P-Value	Confidence Interval 95%	
D2.LogRE	0.086259	0.010971	7.86	0.000*	0.064756	0.107762
D2. LogL	0.541478	0.016815	32.2	0.000*	0.508522	0.574434
D2.LogK	0.529451	0.015506	34.15	0.000*	0.49906	0.559842
Prob > Chi2	0.0000*					
Number of Observations	214					
R-Kare	0.9795					
Root MSE	0.02498					
Wald chi2(3)	10218.6					

Note: * The null hypothesis was rejected because the P value and probability value were lower than the critical value (0.05%). In other words, there is a correlation between the error term and delayed variables of all series. However, this method is considered invalid because autocorrelation was not considered.

The appropriate test method is the Arellano–Bond GMM (generalized method of moments). However, in order to use this method, the second order in the model autocorrelation should be absent (Roodman, 2009). First and second-degree autocorrelation tests should be conducted. In this context, models without second-degree autocorrelation are considered appropriate. The autocorrelation test results are given in Table 6.

Table 6. Arellano–Bond autocorrelation test.

Degree	z	Prob>z
1	-4.5319	0.0000*
2	-0.51498	0.6066*

Note: * P values indicate that there is no second-degree autocorrelation.

Table 7. Two-stage Arellano–Bond GMM * dynamic panel data test results.

LogGSYH	Coefficient	Standard Errors	Z-Value	P-Value	95% c.i	
D2.L1.LogGSYH	-0.016207	0.000738	-21.97	0	-0.017653	-0.014761
D2.LogL***	0.598481	0.022674	26.4	0.000**	0.554041	0.642921
D2.LogRE***	0.092941	0.005769	16.11	0.000**	0.081635	0.104248
D2.LogK***	0.456092	0.012082	37.75	0.000**	0.432413	0.479772
GMM türü	L(2/.).D2.LogGSYH					
Standard	D2.LogL D2.LogK D2.LogRE					
Wald chi2(4)	74325.05					
Prob > chi2	0					

Note: * In the generalized moments method (GMM), normally the first differences are estimated in the context of the generalized least squares method by converting the dynamic fixed effect model vehicle with variables. However, since the variables are stationary from the second difference in the unit root test, the second difference variables are used. Making the model robust error is not preferred because this causes deviation in standard error amounts and decreases the reliability of the final results. ** P values and probability values mean that the final test result is significant and positive because these values are lower than the critical value (0.05%). *** The second difference of logarithm independent variables was taken and included in the test.

As shown in Table 6, since the second order P value is higher than the error margin (0.05%) according to the probability results and (z) statistics, the model was not autocorrelated from the second order ($P = 0.1483 > 0.05$). Therefore, using the Arellano–Bond GMM method was considered to be appropriate to generate consistent results in the research. In this context, the relationship between independent variables and the dependent variable was examined using the Arellano–Bond test for the final parameter estimation, and Table 7 shows the results. The statistically significant and positive values of P of L, K and RE indicate that labor, capital and renewable energy are related to GDP. The relationship between renewable energy and GDP is meaningful and positive, and this shows that the policies regarding renewable energy sources play an active role in the selected EU countries, and the factor elasticity coefficients of production were shown to be positive, which is economically consistent and significant.

6. CONCLUSION

The Cobb–Douglas production function of output flexibility coefficients for renewable energy consumption and labor and capital inputs in EU countries selected from 2000 to 2017, it was estimated within the scope of the coefficients obtained as a result of the analysis were found to be statistically and economically significant. The Cobb–Douglas production was converted to linear to form the coefficients of the variables in the function and express the production factor elasticity coefficients. The sum of these coefficients constitutes the output elasticity coefficient, and the findings are summarized as follows. The coefficients estimated as a result of the analysis have received positive values. The elasticity coefficient of production was estimated to be 0.598 for labor, 0.4456 for capital, and 0.093 for renewable energy. The sum of these flexibility coefficients is 1.147, and in the 12 selected EU countries there was an increased yield by scale within the Cobb–Douglas production function. In addition, the largest factor flexibility coefficient among the inputs in the case of explanatory variables belongs to the labor factor, which is followed by capital and renewable energy, respectively.

The flexibility of labor, capital, and renewable energy inputs in the production function between 0 and 1 means that the average product of these inputs is larger than the marginal product. In this context, all of the inputs are located in the second region of production, which is the region where the law of decreasing yields operates. The positive values of the factor flexibility coefficients of the products show that there is a functional complementarity relation between the inputs. An increase in the amount increases the marginal efficiency of the other inputs. The Cobb–Douglas production function estimated by this state produced results compatible with the theory. It would be beneficial for the selected EU countries that produce the most renewable energy to increase their support policies for renewable energy use.

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REFERENCES

Alper, A., & Oguz, O. (2016). The role of renewable energy consumption in economic growth: Evidence from asymmetric causality. *Renewable and Sustainable Energy Reviews*, *60*(C), 953-959.Available at: https://doi.org/10.1016/j.rser.2016.01.123.

Anderson, T. W., & Hsiao, C. (1982). Formulation and estimation of dynamic models using panel data. *Journal of Econometrics*, *18*(1), 47-82.Available at: https://doi.org/10.1016/0304-4076(82)90095-1.

Apergis, N., & Dănuleţiu, D. (2014). Renewable energy and economic growth: Evidence from the sign of panel long-run causality. *International Journal of Energy Economics and Policy*, *4*(4), 578-587.

Apergis, N., & Payne, J. E. (2010a). Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy*, *38*(1), 656-660.Available at: https://doi.org/10.1016/j.enpol.2009.09.002.

Apergis, N., & Payne, J. E. (2010b). Renewable energy consumption and growth in Eurasia. *Energy Economics*, *32*(6), 1392-1397.Available at: https://doi.org/10.1016/j.eneco.2010.06.001.

Apergis, N., & Payne, J. E. (2011a). Renewable and non-renewable electricity consumption–growth nexus: Evidence from emerging market economies. *Applied Energy*, *88*(12), 5226-5230.Available at: https://doi.org/10.1016/j.apenergy.2011.06.041.

Apergis, N., & Payne, J. E. (2011b). The renewable energy consumption–growth nexus in central America. *Applied Energy*, *88*(1), 343-347.Available at: https://doi.org/10.1016/j.apenergy.2010.07.013.

Apergis, N., & Payne, J. E. (2012). Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. *Energy Economics*, *34*(3), 733-738.Available at: https://doi.org/10.1016/j.eneco.2011.04.007.

Aslan, A., & Ocal, O. (2016). The role of renewable energy consumption in economic growth: Evidence from asymmetric causality. *Renewable and Sustainable Energy Reviews*, *60*(C), 953-959.Available at: https://doi.org/10.1016/j.rser.2016.01.123.

Bhattacharya, M., Paramati, S. R., Ozturk, I., & Bhattacharya, S. (2016). The effect of renewable energy consumption on economic growth: Evidence from top 38 countries. *Applied Energy*, *162*(1), 733-741.Available at: https://doi.org/10.1016/j.apenergy.2015.10.104.

Bonn, M., Heitmann, N., Reichert, G., & Voßwinkel, J. (2015). Climate and energy: Comments on an evolving framework policy 2030. Retrieved from: cepInput.https://www.cep.eu/Studien/cepInput_Klima_und_Energie/cepInput_Climate_and_Energy_Policy_2020-2030.pdf, Accessed 15.11.2019].

Breitung, J., & Pesaran, M. H. (2005). Unit roots and cointegration in panels. Cambridge Working Papers in Economics, 0535, University of Cambridge, Faculty of Economics.

Bulut, U., & Muratoglu, G. (2018). Renewable energy in Turkey: Great potential, low but increasing utilization, and an empirical analysis on renewable energy-growth nexus. *Energy Policy*, *123*, 240-250.Available at: https://doi.org/10.1016/j.enpol.2018.08.057.

Çermikli, A. H., & Tokatlıoğlu, İ. (2015). The effect of technological development on energy intensity in high and middle income countries. *Mustafa Kemal University Institute of Social Sciences Dergisi*, *12*(32), 1-22.

Choi, I. (2001). Unit root tests for panel data. *Journal of International Money and Finance, 20*(2), 249-272.Available at: https://doi.org/10.1016/s0261-5606(00)00048-6.

Chudik, A., Pesaran, M. H., & Tosetti, E. (2011). Weak and strong cross-section dependence and estimation of large panels. *14*(1), C45-C90.Available at: https://doi.org/10.1111/j.1368-423x.2010.00330.x.

Chudik, A., & Pesaran, M. H. (2013). Large panel data models with cross-sectional dependence: A survey. Cafe Research Paper No. 13.15.

De Hoyos, R. E., & Sarafidis, V. (2006). Testing for cross-sectional dependence in panel-data models. *The Stata Journal, 6*(4), 482-496.

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, 99*(C), 1126-1136.Available at: https://doi.org/10.1016/j.renene.2016.07.078.

Durgün, B., & Durgün, F. (2018). Between renewable energy consumption and economic growth causality relationship: Case of Turkey. *International Review of Economics and Management, 6*(1), 1-27.

European commission. (2019a). 2020 climate & energy package. Retrived from: https://ec.europa.eu/clima/policies/stratigies/2020_en, (25.11.2019).

European Commission. (2019bc). Energy strategy and energy union: Secure, competitive, and sustainable energy.Retrieved from: https://ec.europa.eu/energy/en/topics/energy-stratigies-and-energy-unioun (19.10.2019).

Hoechle, D. (2007). Robust standard errors for panel regressions with cross-sectional dependence. *The Stata Journal, 7*(3), 281-312.Available at: https://doi.org/10.1177/1536867x0700700301.

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics, 115*(1), 53-74.Available at: https://doi.org/10.1016/s0304-4076(03)00092-7.

IRENA. (2019). Renewable energy statistics, 2019. International renewable energy agency. Retrieved from: https://www.irena.org/publications/2019/Jul/Renewable-energy-statistics-2019, (15.12.2019).

Ito, K. (2017). CO2 emissions, renewable and non-renewable energy consumption, and economic growth: Evidence from panel data for developing countries. *International Economics, 151*(C), 1-6.

Kahia, M., Ben Aissa, M., & Charfeddine, L. (2017). Renewable and non-renewable energy use-economic growth nexus: The case of MENA net oil importing countries. *Renewable and Sustainable Energy Reviews, 71*(C), 127-140.

Koçak, E., & Şarkgüneşi̇, A. (2017). The renewable energy and economic growth nexus in black sea and Balkan countries. *Energy Policy, 100*(C), 51-57.

Kula, F. (2014). The long-run relationship between renewable electricity consumption and GDP: Evidence from panel data. *Energy Sources, Part B: Economics, Planning, and Policy, 9*(2), 156-160.

Kurumu, T. D. (2011). *Dictionary of economics terms*. Ankara: Turkish Language Association Publications.

Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics, 61*(S1), 631-652.Available at: https://doi.org/10.1111/1468-0084.61.s1.13.

Marinaş, M.-C., Dinu, M., Socol, A.-G., & Socol, C. (2018). Renewable energy consumption and economic growth. Causality relationship in central and Eastern European countries. *PloS One, 13*(10), e0202951.Available at: https://doi.org/10.1371/journal.pone.0202951.

Menegaki, A. N. (2011). Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis. *Energy Economics, 33*(2), 257-263.Available at: https://doi.org/10.1016/j.eneco.2010.10.004.

Moon, H. R., & Perron, B. (2004). Testing for a unit root in panels with dynamic factors. *Journal of Econometrics, 122*(1), 81-126.Available at: https://doi.org/10.1016/j.jeconom.2003.10.020.

Ocal, O., & Aslan, A. (2013). Renewable energy consumption–economic growth nexus in Turkey. *Renewable and Sustainable Energy Reviews, 100*(28), 494-499.Available at: https://doi.org/10.1016/j.rser.2013.08.036.

Pesaran, M. H., Smith, L. V., & Yamagata, T. (2013). Panel unit root tests in the presence of a multifactor error structure. *Journal of Econometrics, 175*(2), 94-115.Available at: https://doi.org/10.1016/j.jeconom.2013.02.001.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics, 22*(2), 265-312.Available at: https://doi.org/10.1002/jae.951.

Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels. Cambridge Working Papers in Economics, 0435, University of Cambridge, Faculty of Economics.

Rafindadi, A. A., & Ozturk, I. (2017). Impacts of renewable energy consumption on the German economic growth: Evidence from combined cointegration test. *Renewable and Sustainable Energy Reviews, 75*(C), 1130-1141.Available at: https://doi.org/10.1016/j.rser.2016.11.093.

Roodman, D. (2009). How to do xtabond2: An introduction to difference and system GMM in Stata. *The Stata Journal, 9*(1), 86-136.Available at: https://doi.org/10.1177/1536867x0900900106.

Salim, R., Hassan, K., & Shafiei, S. (2014). Renewable and non-renewable energy consumption and economic activities: Further evidence from OECD countries. *Energy Economics, 44*(C), 350-360.Available at: https://doi.org/10.1016/j.eneco.2014.05.001.

Sari, R., & Soytas, U. (2007). The growth of income and energy consumption in six developing countries. *Energy Policy, 35*(2), 889-898.Available at: https://doi.org/10.1016/j.enpol.2006.01.021.

Shahbaz, M., Loganathan, N., Zeshan, M., & Zaman, K. (2015). Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan. *Renewable and Sustainable Energy Reviews, 100*(44), 576-585.Available at: https://doi.org/10.1016/j.rser.2015.01.017.

Songur, M. (2019). In Turkey, labor, capital and energy substitution between flexibility: Translog production function approach. *Journal of Erciyes University Faculty of Economics and Administrative Sciences, 54*, 114-137.

Stamatios, N., S., M., Grigorios, K., Garyfallos, A., Miltiadis, C., Spyros, G., . . . Apostolia, K. (2018). Renewable energy and economic growth: Evidence from European countries. MDPI. *Sustainability, 10*(26), 1-13.

TR Ministry of Foreign Affairs. (2017). Chapter 15 - energy. Republic of Turkey ministry of foreign affairs, presidency of the European Union. Retrieved from: https://www.ab.gov.tr/fasil-15-enerji_80.html [Accessed 10.12.2019].

Yılmaz, S. A. (2014). Potential field in green jobs in renewable energy and Turkey. T. C. Ministry of development (pp. 73). Ankara: General Directorate of Social Sectors and Coordination.