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The renewable energy and economic growth nexus in European countries

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Abstract

The study examines the long-run relationship between renewable energy consumption and economic growth within the framework of the traditional production function in 29 European countries from 1995 to 2016. The study was based on the panel unit root tests, panel cointegration test—the Kao (1999), Pedroni (1999, 2004), Westerlund (2005) and fully modified ordinary least squares estimator and dynamic ordinary least squares estimator. The study found that there is a long-term equilibrium relationship between economic growth and renewable energy consumption and that renewable energy consumption has a positive impact on economic growth. The results suggest that the use of renewable energy as a global commodity in the process of economic growth is highly significant. Therefore, policies to promote renewables can provide for economic growth, an increase in renewables and the reduction of greenhouse gas (GHG) emissions, and ensure important sustainable development goals.

KEYWORDS: cointegration, economic growth, panel data analysis, renewable energy, sustainable development

1 | INTRODUCTION

The dependence on traditional energy sources has brought many global problems. Energy independence and the security of supply, energy price shocks, nonrenewable features of oil, natural gas, and coal as energy sources and global warming are considered the most fundamental global problems (Koçak & Şarkgüneşi, 2017; Sadorsky, 2009). This has forced countries and societies to find alternative energy sources to conventional energy sources (Bilgili & Ozturk, 2015; Ozturk & Bilgili, 2015). Attention was paid to renewable energy sources as a significant alternative source of energy (Apergis & Payne, 2010; Lu et al., 2019), and replacing traditional energy sources with renewable energy sources has become the main solution tool (Kasperowicz, Pinczyński, & Khabdullin, 2017; Stavytskyy, Kharlamova, Giedraitis, & Šumskis, 2018; Tvaronaviciené, Prakapiené, Garškaité-Milvydiené, Prakapas, & Nawrot, 2018; Yildirim, 2014).

However, according to Stefan, Vintilă, and Gherghina (2017) the literature provides scant evidence on the renewable energy consumption-economic growth nexus in European Union (EU) countries. Therefore, renewable energy has been the subject of great interest among academics. It is this interest that has been the motivation of the work.

The aim of this paper is to explore the relationship between economic growth and renewable energy consumption for 29 countries of Europe—Belgium, Bulgaria, Czechia, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, United Kingdom, Iceland, Norway for the period of 1995-2016. In order to meet the objective of the study, we use the panel data approach. First, we perform the panel unit root tests to estimate the order of integration of time series. Second, we use cointegration tests for the panel of countries, which provides the information about the existence of a long-run relationship between the analyzed economic aggregates. Next, we use the fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) techniques to estimate the cointegration vector for cointegrated panels.

The remainder of the article is structured as follows: Section 2 presents a brief literature review. Section 3 presents the data used in our model and describes the model and the econometric methodology used in the analysis. Section 4 reports the empirical results for the unit root testing, the cointegration testing and results for the long-run cointegrating vectors. The last section is the conclusion.

2 | LITERATURE REVIEW

In recent years, renewable energy production and technologies have become a central element of energy policy. The production of renewable energy sources is supported by subsidies and tax rebates. These activities reduce the costs of renewable energy production and that is why in many cases renewable energy has become competitive in relation to conventional energy (McCauley, 2015; Tabrizian, 2019).

An emerging trend in the global energy sector led to a debate on the role of renewable energy development in relation to economic growth (Apergis & Payne, 2012; Bhattacharya, Paramati, Ozturk, & Bhattacharya, 2016; Inglesi-Lotz, 2016; Lund, 2007; Okuneviciute Neverauskiene & Rakauskiene, 2018), following the studies analyzing the relationship between economic growth and energy consumption, which has become a well-liked area of research in the economical literature (Kasperowicz and Štreimikiené, 2016a, 2016b).

The theory of economic growth developed for a single-sector model by Robert Solow (Solow, 1956, 1957) became the most used growth theory in the economical literature. A very similar model was developed at about same time by Trevor Swan (Swan, 1956). What was the main characteristics of the Solow-Swan model was the explanation of the logarithmic output growth rate as the sum of output elasticities with respect to capital, labor and time, multiplied by their growth rates. Consequently, the Solow-Swan model depends on only two independent factors of production, namely, labor supply and capital stock. As noted by Ayres and Warr (2009), these two factors of production could not explain the observed growth of the U.S. economy from 1909 through 1949 and the unexplained “Solow residual” accounted for over 85 % of the output growth. The accumulations of abstract labor and abstract capital with an exogenous driver called “technological progress” were the only variables in the Solow model, as well as in its variants. The origins of physical production in the neoclassical theory remained unexplained.

The opportunity of exploitation and involvement of energy variables into the output model emerged after the oil crisis and embargo in 1973-1974. At the time, energy prices rapidly rose and the economists wanted to estimate the relationship between the energy and economic growth. Jorgenson (1983,1984) introduced a logarithmic production function of four factors, known as KLEM (capital, labor, energy, materials).

A much simpler approach was presented by Allen et al. (1976) and Hannon and Joyce (1981). They estimated a three-factor Cobb-Douglas production function incorporating energy as one of the endogenous factors. This study opened a wide range of research based on models incorporating energy variables into the growth model. Following the rising consumption of renewables dictated by the ongoing environment-friendly energy production, the incorporation of renewable energy could fill the possible cognitive limitations of the conventional model. The authors decided to enlarge the model by adding one of the key factors of today's economies. The environment-friendly development achieved by using more renewables is one of the main goals of the European economies.

Many scholars (Al-mulali, Fereidouni, Lee, & Sab, 2013; Apergis & Payne, 2010, 2011; Aslan & Ocal, 2016; Bhattacharya et al., 2016; Bilgili, 2015; Bilgili & Ozturk, 2015; Inglesi-Lotz, 2016; Koçak & Şarkgüneşi, 2017; Lin & Moubarak, 2014; Ozturk & Bilgili, 2015; Sadorsky, 2009; Shahbaz, Loganathan, Zeshan, & Zaman, 2015; Shahbaz, Rasool, Ahmed, & Mahalik, 2016) found significant long-run relationship between the renewable energy consumption and economic growth. Some studies found the existence of bidirectional longterm causality relationship between renewable energy consumption and economic growth (Al-mulali et al., 2013; Apergis & Payne, 2012; Bilan etal., 2019; Lin & Moubarak, 2014).

However, some studies (Apergis & Payne, 2012; Dogan, 2015; Menegaki, 2011; Ocal & Aslan, 2013) did not confirm causality between renewable energy consumption and gross domestic product (GDP). Other studies conclude that EU countries must increase the use of new technology and renewable energy capacity in order to align environmental policies towards more efficient energy use and sustainable development (Fotis & Polemis, 2018).

3 | DATA AND METHODOLOGY

3.1 | The data

The data for calculation was taken from Eurostat databases. The financial data was adapted to reality with the use of Eurostat chain linked volumes. Then, the data were converted to their logarithms, which allowed us to present the relationships between variables in an additive equation. The data we used are: gross fixed capital (K), renewable energy consumption (E), labor (L), and GDP.

The research covers the period from 1995 to 2016 for 29 European countries. In total, we are working with 638 observations of each variable, which ensures the statistical validity of our study and enables us to conclude and give policy implications.

3.2 | The methodology

To examine the nexus between energy consumption and GDP, we propose a framework based on the conventional neo-classical one-sector aggregate production function. This approach follows the method employed by Ghali and El-Sakka (2004) to time series data analysis, which was adopted to panel data analysis by Soytas and Sari (2006). We examine the long-run relationship in a three factor production function:

$$\text{GDP} = f(K, L, E), \tag{1}$$

where: GDP = ln of real gross domestic product; K = ln of real gross fixed capital; E = ln of renewable energy consumption; L = ln of labor (active population).

Using the applied GDP model, we suppose that we have nonstationary time series K, L, E, and GDP, which become stationary when differenced (1(1) series) so that some linear combination of K, L, E, and GDP is stationary (aka, I[0]). Then, we say that K, L, E, and GDP are cointegrated. In other words, while neither K, L, E together nor GDP alone hovers around a constant value, some combination of them does, so we can think of cointegration as describing a particular kind of a long-run equilibrium relationship.

Before testing for cointegration, we performed four panel unit root tests—Levin, Lin, and Chu (2002); Im, Pesaran, and Shin (2003); Harris and Tzavalis (1999); Breitung (2000)—to establish the order of integration.

Levin et al. (2002) test assumes that there is a common unit root process so that p, is identical across cross-sections. The test employs a null hypothesis of a unit root. LLC test consider the following basic Augmented Dickey Fuller (ADF) specification:

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta y_{it-j} + X_{it}' \delta + \varepsilon_{it,} \tag{2}$$

where a common $\alpha = p$-1 is assumed and the lag order for the difference terms, pi, to vary across cross-sections, is allowed. The H_0 is α=1 (there is a unit root) and the alternative H_1 is α <0 (there is no unit root).

Im et al. (2003) test allows for individual unit root processes so that p_i may vary across cross-sections. The test begins by specifying a separate ADF regression for each cross-section (on the model of Equation 2). The null hypothesis may be written as—H_0: $\alpha_i = 0$, for all i, while the alternative hypothesis is given by:

$$H_1 : \begin{cases} \alpha_i < 0 & for\ i = 1,2,\ldots,N_1 \\ \alpha_i = 0\ for\ i = N+1, N+2, \ldots, N \end{cases}. \tag{3}$$

(i may be reordered), which can be interpreted as a nonzero fraction of the individual processes, is stationary. The rejection of the null hypothesis does not necessarily imply that the unit root null is rejected for all i. The test does not require strongly balanced data, but there can be no gaps in each individual time series.

The Harris and Tzavalis (1999) test is similar to the LLC test. It also assumes that all panels have the same autoregressive parameter so that the alternative hypothesis is simply rho <1. In contrast to the LLC test, the HT test assumes a fixed number of time periods, T. The HT test requires strongly balanced panels, which is similar to the LLC test. The HT test also assumes homogeneous variance, while the Levin-Lin test does not. The test, as implemented, uses y_{it} rather than Δy_{it} as the dependent variable, which means that the test is for p = 1 rather than p = 0. It has large N, fixed T asymptotics, again, with the centered and rescaled test statistic being N (0,1).

The LLC and HT tests are both based on regression statistics t, which are then adjusted to reflect the fact that, according to the null hypothesis, statistics t have a nonzero mean due to the inclusion of panel-specific means or trends. In contrast the test of Breitung (2000), the test transforms the data before computing the regressions so that the standard t statistics can be used. The test requires that the panels be strongly balanced and assumes that all panels have a common autoregressive parameter and requires strongly balanced panels. The null hypothesis assumes that all series contain a unit root. The alternative hypothesis is that rho <1, which means stationary series. Breitung and Das (2005) observed that the test also has power in the heterogeneous panel case, where each panel can possess its own autoregressive parameter, although the test is optimal in case where all panels own the same autoregressive parameter. The Monte Carlo (Breitung, 2000) simulations, where N = 20 and T = 30 were considered, indicates that Breitung test is essentially more powerful than other panel unit-root tests for the modest-size dataset.

When the existence of a panel unit root has been established, the process is supposed to be integrated of order one, denoted I(1). The issue emerges whether there exists a long-run equilibrium relationship between the analyzed variables. Once a linear combination of several integrated of order one series is stationary, the series are said to be cointegrated (Engle & Granger, 1987). We test for cointegration, because it implies that the I(1) series are in a long-run equilibrium; they move together, although the group of them can wander arbitrarily.

The tests of Kao (1999), Pedroni (1999, 2004), and Westerlund (2005) implemented in the study merge statistics evaluated for each individual in the panel, thereby, they produce a higher power test. Moreover, the limiting distribution of the combined test tends to a standard normal distribution after proper standardization, whereas the tests for cointegration based on a single time series have nonstandard distributions.

All tests are based on the following panel-data model for the I (1) dependent variable y_{it}, where i = 1 ,N represents the panel (individual) and t = 1,..., T_i denotes time:

$$y_{it} = x_{it}'\beta_i + z_{it}'\gamma_i + e_{it.} \qquad (4)$$

For each panel i, each of the covariates in x_{it} is an I(1) series. All the tests demand that the covariates are not cointegrated between themselves. The Pedroni and Westerlund tests allow for a maximum of seven covariates in x_{it}.β_i represents the cointegrating vector, which may vary across panels. Υ_i, denotes a vector of coefficients on z_{it}, the deterministic terms that control for panel-specific effects and linear time trends. eit denotes the error term.

The tests share the same null hypothesis holding that y_{it} and x_{it} are not cointegrated by testing the nonstationarity of e_t. The rejection of the null hypothesis indicates that e_{it} is stationary and the analyzed series y_{it} and x_{it} are cointegrated. The alternative hypothesis of the Pedroni tests, the Kao tests, and all the panels of the Westerlund test denotes that the variables are in all panels cointegrated. The alternative hypothesis of some panels of the Westerlund test is that the variables are cointegrated in some of the panels.

After estimating the panel cointegration, the long-run cointegration vector was established using FMOLS developed by McCoskey and Kao (1998), Phillips and Moon (1999), and DOLS developed by

McCoskey and Kao (1998) and Kao and Chiang (2000). The selection conditions of the methods are discussed in articles by McCoskey and Kao (1998), Kao and Chiang (2000). The authors indicated that the panel DOLS is less biased than the panel OLS and FMOLS estimators using Monte Carlo simulations in small samples. The panel DOLS estimator has better sample properties rather than the panel OLS and FMOLS estimators (Kao & Chiang, 2000).

4 | DATA ANALYSIS AND FINDINGS

4.1 | Testing for the existence of unit root

We use the panel unit root tests to identify the order of integration of each variable. We perform four different statistics described above. The results of the LLC, IPS, HT, and Breitung panel unit root tests for each of the variable are given in Table 1. We perform each test for the level and first difference of variables.

In the case of the level of variables the null hypothesis that variables assume common and individual unit root process cannot be rejected. Unit tests give different results in terms of the stability of level values of the series. However, all statistics show that the series are stable at the first difference. In other words, the series are integrated of first order I(1). In this case, a long-term balance relationship between the variables is possible.

4.2 | Panel cointegration testing results

We are interested in the long-run effect of renewable energy consumption, gross fixed capital and labor on economic growth. The cointegrating relationship is specified as:

$$\mathrm{GDP}_{it} = \gamma_i + \beta_1 \mathrm{K}_{it} + \beta_2 \mathrm{E}_{it} + \beta_3 \mathrm{L}_{it} + e_{it}, \qquad (5)$$

where Υ_i is the panel-specific mean and the cointegrating parameters β_1, β_2 , and (β_3 are the same across panels. We assume that each series is I(1).

First, we performed the Kao test of cointegration. We used a model with panel-specific means and no time trend, as reported in Table 2. The AR parameter that determines the presence or lack of cointegration is assumed to be the same for all panels. By default, the Kao tests in Stata uses a Bartlett kernel with Newey and West (1994) automatic lag selection algorithm. The ADF t statistics also includes lagged differences of the dependent variable to control for serial correlation.

The output reports the test statistics with their respective p-values. Only in the case of the ADF t statistics, the null hypothesis cannot be rejected. All the rest test statistics reject the null hypothesis of no cointegration in favor of the alternative hypothesis of the existence of a cointegrating relation among economic growth, gross fixed capital, renewable energy consumption, and labor.

TABLE 1 Test results for panel unit roots

Variable		Method							
		Levin, Lin and Chu		Im, Pesaran, and Shin		Harris and Tzavalis		Breitung	
		Constant	c&trend	Constant	c&trend	Constant	c&trend	Constant	c&trend
GDP	Statistic	−6.3395	−6.2232	−2.5159	−0.0117	0.9368	0.8504	10.4326	3.7141
	Prob.	0.0000	0.0000	0.0059	0.4953	0.9963	1.0000	1.0000	0.9999
ΔGDP	Statistic	−8.5298	−6.2821	−7.2412	−8.3877	0.3530	0.4130	−9.8232	−7.9313
	Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
E	Statistic	−1.4168	−15.3979	3.5213	−5.5771	0.6011	−0.0318	9.3585	−1.0568
	Prob.	0.0783	0.0000	0.9998	0.0000	0.0000	0.0000	1.0000	0.1453
Δ*E*	Statistic	−18.5386	−11.6728	−12.8085	−12.8605	−0.4816	−0.4780	−8.4339	−8.4096
	Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K	Statistic	−5.9520	−5.9111	−1.4720	−2.6279	0.8447	0.7424	3.6876	2.4281
	Prob.	0.0000	0.0000	0.0705	0.0043	0.1612	0.9351	0.9999	0.9924
Δ*K*	Statistic	−8.1263	−5.8715	−7.7887	−8.1140	0.2117	0.2316	−7.5063	−4.4008
	Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L	Statistic	−3.1169	−2.2591	5.1140	1.6993	0.9349	0.8434	5.8743	5.4874
	Prob.	0.0009	0.0119	1.0000	0.9554	0.9953	1.0000	1.0000	1.0000
Δ*L*	Statistic	−6.5694	−6.8874	−8.5267	−10.3281	0.2394	0.2909	−11.9035	−9.4054
	Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TABLE 2 Kao test for cointegration

Ho: No cointegration	Number of panels	29
Ha: All panels are cointegrated	Number of periods	20
Cointegrating vector: Same		
Panel means: Included	Kernel:	Bartlett
Time trend: Not included	Lags:	1.45 (Newey-West)
AR parameter: Same	Augmented lags:	1
	Statistic	*p*-Value
Modified Dickey–Fuller *t*	−3.9833	.0000
Dickey–Fuller *t*	−8.5681	.0000
Augmented Dickey–Fuller *t*	−1.2194	.1114
Unadjusted modified Dickey–Fuller *t*	−5.0980	.0000
Unadjusted Dickey–Fuller *t*	−8.9649	.0000

TABLE 3 Pedroni test for cointegration

Ho: No cointegration	Number of panels	29
Ha: All panels are cointegrated	Number of periods	21
Cointegrating vector: Panel specific		
Panel means: Included	Kernel:	Bartlett
Time trend: Not included	Lags:	0.00 (Newey–West)
AR parameter: Panel specific	Augmented lags:	1
	Statistic	*p*-Value
Modified Phillips–Perron *t*	2.0244	.0215
Phillips–Perron *t*	−3.0479	.0012
Augmented Dickey–Fuller *t*	−4.3534	.0000

Continuing with our study, we performed the Pedroni test. Pedroni (1999, 2000, 2001, 2004) refers to the tests based on panel-specific AR parameters as "between-dimension tests" and refers to the tests based on the same AR parameters as "within-dimension tests." The tests allow for panel-specific cointegrating vectors. This heterogeneity distinguishes Pedroni tests from those derived by Kao. Another difference is that the Pedroni tests allow the AR coefficient to vary over panels, while the Kao tests assumed the same AR coefficient. The cointegrating relationship is specified as:

$$GDP_{it} = \gamma_i + \beta_{1i}K_{it} + \beta_{2i}E_{it} + \beta_{3i}L_{it} + e_{it}, \tag{6}$$

where β_1, β_{2i}, and β_{3i} represent panel-specific cointegration parameters.

The results of the Pedroni panel cointegration test statistics are shown in Table 3.

All the test statistics reject the null hypothesis of no cointegration in favor of the alternative hypothesis that the variables are cointegrated in all panels with a panel-specific cointegrating vector.

Pedroni cointegration tests allow us to specify an alternative hypothesis, which assumes the same AR parameter across all panels as well (see Table 4).

This time, two test statistics reject the null hypothesis of no cointegration without any doubts. Taking into consideration the 10% of statistical significance, we can acknowledge the cointegration in one case of test statistics. Only one statistics does not confirm the cointegration relationship between the analyzed variables at the satisfactory level.

TABLE 4 Pedroni test for cointegration ar (same)

Ho: No cointegration	**Number of panels**	**29**
Ha: All panels are cointegrated	Number of periods	21
Cointegrating vector: Panel specific		
Panel means: Included	Kernel:	Bartlett
Time trend: Not included	Lags:	0.00 (Newey–West)
AR parameter: Same	Augmented lags:	1
	Statistic	*p*-Value
Modified variance ratio	−4.5763	.0000
Modified Phillips–Perron *t*	1.2840	.0996
Phillips–Perron *t*	−1.2080	.1135
Augmented Dickey–Fuller *t*	−2.3242	.0101

TABLE 5 Westerlund test for cointegration (panel specific AR)

Ho: No cointegration	**Number of panels**	**29**
Ha: Some panels are cointegrated	Number of periods	22
Cointegrating vector: Panel specific		
Panel means: Included		
Time trend: Not included		
AR parameter: Panel specific		
	Statistic	*p*-Value
Variance ratio	−2.4383	.0074

Continuing with our research, we performed the Westerlund test. Westerlund (2005) derived a pair of Vector Regression (VR) test statistics for the null hypothesis of no cointegration. The default test uses a model in which the AR parameter is panel specific and for Abbreviations: DOLS, dynamic ordinary least squares; FMOLS, fully modified ordinary least squares.

TABLE 7 Panel long-run parameters for 29 European countries

Variable	**Panel DOLS**			**Panel FMOLS**		
	Coefficient	*t*-Statistic	*p*-Value	Coefficient	*t*-Statistic	*p*-Value
K	0.448048	15.84591	.0000	0.437516	24.22823	.0000
E	0.157588	8.427063	.0000	0.158970	11.46468	.0000
L	0.179064	0.725873	.4686	0.226854	1.312000	.1900

Abbreviations: DOLS, dynamic ordinary least squares; FMOLS, fully modified ordinary least squares.

which the alternative hypothesis is that the series in some of the panels are cointegrated. Specifying all the panel option produces the results for a test in which the alternative hypothesis is that the series in all the panels are cointegrated, and this test uses a model in which the AR parameter is the same over the panels. The cointegrating relationship is specified as:

$$GDP_{it} = \gamma_i + \beta_{1i}K_{it} + \beta_{2i}E_{it} + \beta_{3i}L_{it} + e_{it}, \quad (7)$$

where β_1, β_{2i} , and β_{3i} are panel-specific cointegration parameters. We now test the null hypothesis of no cointegration under the alternative that some of the β_{1i}, β_{2i} , and β_{3i} produce cointegrated series. The results of the panel cointegration test statistics is shown in Table 5.

The VR test statistics rejects the null hypothesis of no cointegration between economic growth, gross fixed capital, renewable energy consumption, and labor in favor of the alternative that at least some panels are cointegrated.

Finally, we use the Westerlund test with all panel option to test the null hypothesis of no cointegration under the alternative hypothesis that all panels are cointegrated. This test is based on the model in which the AR parameter is the same over the panels (Table 6).

The VR statistics rejects the null hypothesis of no cointegration. This implies all panels are cointegrated.

In general, the statistical tests, taking into consideration the 5% significance level, reject the null hypothesis of no cointegration. We found the existence of cointegration relationships between economic growth and the variables: renewable energy consumption, gross fixed capital, and labor. The analyzed variables move together in the long-run, so one can state that there is a long-run relationship for all the sample countries.

5 | PANEL COINTEGRATION ESTIMATION

The next step was to estimate the long-run cointegrating vector between energy consumption and economic growth, we employed the panel FMOLS and DOLS methods. We performed the panel data model FMOLS and DOLS with pooled weighted estimation method. The panel DOLS estimator values were determined following the assumption of one lag and one lead in the regressors change. Table 7 outlines the results of the panel FMOLS and DOLS estimators for all the sample countries.

For the variables E and K the panel FMOLS and DOLS estimators produce similar results in terms of the sign and statistical significance, whereas the magnitudes of the estimated coefficients are slightly different. All the coefficients are statistically significant at the 1% level of significance. We found a positive relationship between renewable energy consumption, gross fixed capital and economic growth. The panel DOLS results suggest that a 1% increase in renewable energy consumption increases GDP by 0.16%, a 1% increase in gross fixed capital increases GDP by 0.44%. In the case of labor, the panel FMOLS and DOLS estimators produce similar results in terms of the sign, but L is not a significant variable.

6 | DISCUSION

In sum, we found that renewable energy consumption together with gross fixed capital have positive and statistically significant impact on economic growth in the long run. The economies of the analyzed panel European countries are energy dependent and relied on the renewable energy consumption. Therefore, renewable energy is becoming an important contributing factor to economic growth for the countries. The study contributes to the literature, following the study of Stefan et al. (2017) who found the positive influence of primary production of renewable energies on the economic growth of European countries.

Similar to the factors that affect the economic growth, renewable energy is likewise an essential determinant of economic growth in European countries.

The findings of this study are in line with other studies analyzing the impacts of renewable energy consumption on economic growth (Bilgili, 2015; Inglesi-Lotz, 2016; Koęak & Sarkgune§i, 2017; Simionescu, Bilan, & Štreimikiené, 2019). However, the results are in contradiction to findings of Menegaki (2011). In the case of total employment, we found a positive relationship in relation to economic growth, but it is not a significant variable.

Further studies are necessary to analyze the impact of other factors on economic growth, like the increase of energy efficiency, the security of energy supply, the use of cogeneration etc. The clustering of countries based on the impact of renewable energy consumption of economic growth should be investigated as well.

7 | CONCLUSIONS

Climate change and global warming, energy supply security, and limited reserves of petrol, coal, and natural gas sources make it obligatory to replace classical energy sources with alternative ones. Renewable energy sources as an alternative source show great potential. In this context, the impact of renewable energy consumption on economic growth for 29 European countries during the period 1995-2016 is explored in the frame of traditional production function. Within the context of the research, first the panel unit root tests were calculated, followed by panel cointegration tests and FMOLS estimator and DOLS estimator. According to the estimation results, we reach the conclusion that renewable energy consumption has a positive impact on economic growth. The panel cointegration test results demonstrate that economic growth and renewable energy consumption together with gross fixed capital and labor are cointegrated. Moreover, the results of the panel FMOLS and DOLS estimators reveal that the relationship between renewable energy consumption, gross fixed capital, and economic growth is positive and statistically significant.

For each modeling approach, an increase in renewable energy consumption and in gross fixed capital lead to the growth of GDP.

The results suggest that the use of renewable energy as a global commodity in the process of economic growth is highly significant.

The main finding of the study suggests that renewable energy consumption is an integral part of economic growth, so the economic growth of the analyzed European countries is renewable energy dependent.

The results allow policymakers to better understand renewable energy consumption—economic growth nexus to formulate energy policies. The main recommendation is that policies aiming to replace traditional energy sources with renewable energy sources should be getting stronger support in the European countries. Practices like tax incentives and feed-in prices and quotas for renewables under the energy policies should be followed. Enhanced subsidies can be adopted for renewable energy sources. Systems that will provide an easier and fairer access to the electricity that is produced from renewable energy sources ought to be supported. The adopted Energy Roadmap 2050 has to be effectively implemented, updated and monitored. The policies aimed at improving renewable energy technologies and investments and other financial aids should be pursued.

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