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The Relationship Between Renewable Energy Consumption and Economic Growth in OECD Countries

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Abstract

This study aims to investigate the relationship between renewable energy consumption and economic growth for OECD countries, which increased their GDP by 70.22%, fossil fuel use by 5.18%, and renewable energy use (excluding hydro) by 400% in 2019 compared to 1990. While doing this, it analyzes real GDP, renewable energy consumption, real gross capital, and labor force for 20 OECD countries with annual data for the period 1990-2019. First of all, stationarity tests were used to determine the degree of stationarity of the series. Then, the cointegration relationship was tested with a heterogeneous panel cointegration test and a cointegration relationship was found. The coefficients of all variables were positive and statistically significant. In addition, according to the findings obtained from the error correction models, it has been obtained that there is unidirectional causality from renewable energy consumption to economic growth in both the short and long run. Therefore, the results show that the interdependent relationship between renewable energy consumption and economic growth supports the growth hypothesis. So, for OECD countries, any policy to reduce energy use will hurt economic growth.

Key words: Renewable energy consumption, Growth, Cointegration, Causality, OECD.

JEL Code: C3, O5, Q2, Q3, Q4

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1. Introduction

Global warming and climate changes, which are based on anthropogenic problems, have been discussed frequently in recent years (Stocker, 2013: 13). As a result of the activities carried out with the increase in the demands and needs of people with the globalization process, nature is damaged and negative residues are left on the quality of life of future generations. There is an increase in energy demand due to reasons such as increasing population in the world, increasing industrialization activities, developments in technology, improvements in living standards, and an increase in consumption expenditures. To meet the increasing demand, non-renewable energy sources are preferred. The reason for this preference is that access to these resources is less costly and more easily accessible. With the preference for traditional fossil fuels such as natural gas, coal, and oil, an increase is observed in the emission of carbon dioxide and similar greenhouse gases that cause environmental pollution and global warming. Thus, it becomes inevitable to occur on a global scale, such as decreasing biodiversity, increasing erosion, damage to agricultural production, and air pollution, especially climate changes.

Considering that meeting the increasing energy demand from non-renewable sources can have such negative consequences, the importance of renewable energy sources, which are thought to be cleaner in the world and more beneficial to the environment and nature, has begun to increase. The use of renewable energy such as wind, solar, geothermal, and hydroelectric has been encouraged more in recent years than in the past. Investing in renewable energy sources by governments has started to become government policy. Although the costs are thought to be high by some circles, the necessity of increasing the use of renewable energy sources on behalf of future generations, along with their environmental and nature-friendly feature in the long term, is revealed (IEA, 2019). On the other hand, the fact that non-renewable energy resources are generally concentrated in some regions in the world, and bad experiences such as the oil crisis in the 1970s accelerated the orientation to different energy sources.

Today, two main problems are encountered in reaching energy. First, fossil resources are limited. Although there is no problem with supply today, there will definitely be a problem one day. For this reason, alternative energy sources must be investigated. The second is the global climate change problem. The intense accumulation of CO2 gas in the atmosphere causes global warming (Keleş and Hamamcı, 2002; Evrendilek and Ertekin, 2003). Global warming and climate change problems have brought the relationship between economic growth, energy demand, and environmental pollution to a new dimension. Within the framework of the Kyoto Protocol, it was decided to reduce the amount of greenhouse gas emissions. As a result, many countries have started to increase the use of renewable energy sources by reducing the use of fossil fuels. The International Energy Agency (IEA, 2009) states that the current energy supply and demand is not sustainable in terms of economic, social, and environmental aspects. According to the projections made by the IEA, it is predicted that the primary energy demand will increase by

1.5% annually between 2015 and 2030, and it has been stated that fossil energy resources will be the dominant source of energy demand in this period. Increasing energy demand, especially oil demand, will raise the issue of energy supply security, and it is considered that in 2050, it will cause a CO2 gas emission that is twice the current level. For this reason, many countries, especially developed countries, are searching for alternative sources of fossil fuels. Renewable energy sources are at the forefront of these sources.

According to the current research, it has been obtained that the use of renewable energy in the world increased by 3.92% (2.45% hydro and wind, solar, etc. 7.63%) annually in the 1990-2018 period. This increased rate is higher than the increase in fossil fuels, which increased by 1.76% (1.97% coal, 1.19% oil, and 2.44% natural gas), and nuclear energy, which increased by 1.06% in the same period. There are many reasons for this situation. Volatility in oil prices, the desire of economies to reduce their energy dependency, and the damage caused by carbon emissions to the environment increase the interest of world economies in renewable energy (IEA, 2021).

With globalization, current research has found that world GDP has increased by an average of 2.83% annually from the 1990-2018 period. However, this increase was 1.92% in 20 OECD countries. In addition, while 20 OECD countries had 70% of the world's GDP in 1990, this rate decreased to 55% in 2018 (World Bank, 2021). On the other hand, according to the current research, the total world energy consumption is 1.76% annually, and the world's total fossil fuel use is 1.76% (coal 1.97%, oil 1.19%, and natural gas 2.44%) in the 1990-2018 period. increased was obtained (IEA, 2021). In the 20 OECD countries, the total energy consumption increased by 0.39% and fossil fuel use by 0.18% (coal -1.23%, oil -0.17%, and natural gas 1.80%) annually. In addition, in the same period, while the world's renewable energy (excluding hydro) consumption increased by 7.63%, this increase was 5.91% in 20 OECD countries. Therefore, while fossil fuels are still used at a high rate for the increasing world GDP, the use of fossil fuels in OECD countries is decreasing significantly and the use of renewable energy is increasing instead. In addition, in the same period, world carbon dioxide (CO2) emissions increased by an average of 1.77% annually, while this rate decreased by -0.04% in 20 OECD countries. Therefore, while the world GDP is realized with high energy consumption and high fossil fuel use increases, the GDP increases in OECD countries are realized with less energy consumption, less fossil fuel consumption, and more renewable energy consumption. Therefore, the world realizes "dirty growth" by using fossil fuels at a high rate to increase its GDP. In other words, while the world is growing with more environmental degradation and more climate change, OECD countries are achieving cleaner, more sustainable, and more environmentally oriented growth. Therefore, this study aims to understand the contribution of less energy consumption and less fossil fuel use and the use of renewable energy, as a result of the effective and efficient use of the energy needed for GDP increases with current period data for 20 OECD countries.

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In the literature, the number of studies on renewable energy has increased recently. Based on these studies, the causality relationship related to the effect of energy use on economic growth is based on four basic hypotheses. These are growth, conservation, feedback, and neutrality hypotheses (Apergis and Payne, 2010a; Apergis and Payne, 2010b, Apergis and Payne, 2011a; Apergis and Payne, 2011b; Apergis and Payne, 2012; Bilgili and Ozturk, 2015, Taskin et al., 2020).

With the recent increase in the use of renewable energy, many studies have investigated the relationship between renewable energy consumption and economic growth. Chien and Hu (2008) revealed the existence of a direct relationship between the use of renewable energy resources and capital information in their study of 2003 data from 116 countries through the Structural Equation Model. However, the existence of a significant and direct relationship with GDP could not be reached. In Sadorsky (2009a), he investigated the relationship between income per capita and renewable energy consumption through data from 18 emerging market economies for the period 1994-2003. Using panel unit root tests, FMOLS and DOLS panel model estimators, ECM, and SUR analysis techniques, the findings reveal that an increase in per capita income in the long run also increases renewable energy consumption. With the same econometric methods, Sadorsky (2009b), in his study with the 1980-2005 data of the G-7 countries, revealed that an increase in real GDP and CO2 emissions in the long run positively affects renewable energy consumption. In addition, the existence of a negative effect of increases in oil prices on renewable energy consumption has been obtained. Similarly, Chen et al. (2020) for OECD countries in the period 1995-2015, Ohler and Fetters (2014) for 20 OECD countries in the period 1990-2008, Lin and Moubarak (2014) for China in the period 1977-201, Chang et al. (2015), on the other hand, found that there is a causality between renewable energy consumption and economic growth for the G7 countries in the 1990-2013 period. On the other hand, Menegaki (2011) investigated the relationship between renewable energy consumption and economic growth for 27 European countries in the 1997-2007 period. The findings showed that there is no causality between renewable energy consumption and economic growth.

Apergis and Payne (2010a) investigated the relationship between renewable and non-renewable energy consumption and economic growth with data from 13 Eurasian countries for the period 1992-2007. Panel unit root tests, panel Pedroni cointegration analysis, FMOLS panel model estimator, ECM, and panel causality analyzes were used as econometric methods, and the findings showed that there is a mutual Granger causality relationship between renewable and non-renewable energy consumption and economic growth in the short and long run. The findings of the analysis made for the 1985-2005 period in OECD countries with the same empirical methods, on the other hand, revealed the existence of a mutual Granger causality between renewable energy consumption and economic growth in the short and long run (Apergis and Payne, 2010b). Similarly, Naimoglu (2021) for energy importing emerging economies in the period 1990-2018, Chen et al. (2020) for OECD countries in the period 1995-2015, Ohler and Fetters (2014) for 20 OECD countries in the period 1990-2008, Lin and Moubarak (2014) for China in the period

1977-201, Chang et al. (2015), on the other hand, found that there is a causality between renewable energy consumption and economic growth for the G7 countries in the 1990-2013 period. On the other hand, Menegaki (2011) investigated the relationship between renewable energy consumption and economic growth for 27 European countries in the 1997-2007 period. The findings showed that there is no causality between renewable energy consumption and economic growth.

Tugcu et al. (2012) investigated the relationship between renewable energy and economic growth through the 1980-2009 period data of the G-7 countries. Using panel unit root tests, ARDL cointegration analysis, and Panel causality analysis methods, the authors could not find any causality relationship between per capita income and renewable energy consumption for France, Italy, Canada, and the USA. However, unidirectional causality was found for England and Japan, and mutual causality was found between these two variables for Germany. Apergis and Payne (2012), who investigated similar research in 80 countries' economies, benefited from the 1990-2007 period data through panel unit root tests, panel Pedroni cointegration analysis, FMOLS panel model estimator, ECM, and panel causality analysis methods. The findings revealed that there is a mutual Granger causality between renewable and non-renewable energy consumption and economic growth in the short and long run. Pao and Fu (2013), on the other hand, investigated this relationship in the Brazilian economy through 1980-2010 period data. The findings revealed the existence of unidirectional causality running from non-hydroelectric renewable energy consumption (NREC) to economic growth. On the other hand, a reciprocal causality was found between total energy consumption (TREC) and economic growth. Finally, the existence of unidirectional causality running from economic growth to NREC and TREC has been demonstrated. On the other hand, Omri et al. (2015) For 17 developed and developing countries in the period 1990-2011, Chang et al. (2015) found that there is no causality between renewable energy consumption and economic growth for Canada, Italy, and the USA in the 1990-2011 period, and Bulut and Muratoğlu (2018) for Turkey in the 1990-2015 period. On the other hand, Öcal and Aslan (2013) found that renewable energy consumption harmed the economic growth of Turkey in the 1990-2010 period. Bhattacharya et al. (2016) investigated the relationship between renewable energy consumption and economic growth in 38 countries' economies during the 1991-2012 period. Panel cointegration, DOLS, panel data FMOLS, panel causality methods were used empirically. Findings, for the long term in 57% of the countries; The results show that the increase in renewable energy consumption has a significant and positive effect on economic output. Bakırtaş and Çetin (2016) investigated the relationship between renewable energy consumption and economic growth through the 1992-2010 period data of the G-20 countries. The results revealed that there is a long-term relationship between renewable energy consumption and economic growth. It has been determined that economic growth causes an increase in renewable energy consumption. Inglesi-Lotz (2016) investigated the relationship between renewable energy consumption and economic growth by using the 1990-2010 period data of 34 OECD member countries. In the study, using cointegration, panel pooled estimation, Hausman test methods, it is concluded that renewable energy consumption has a positive and significant effect on economic growth. Özşahin et al., (2017) investigated the relationship between renewable energy consumption and economic development for the BRICS countries and Turkey using the data for the period of 2000-2013. The existence of a long-term relationship between the variables was investigated by Pedroni (1999), Westerlund (2005) Panel CUSUM cointegration test and long-term coefficients were obtained with the Panel ARDL estimator. The empirical findings show that there is a long-term positive relationship between renewable energy consumption and economic development.

Although the subject of this study changes country groups, it is a topic that will remain relevant for a long time. This is because, according to current research, the share of fossil fuels in the world's total energy use in 2018 was 81% (31.49% oil, 26.88% coal, and 22.84% natural gas). On the other hand, the share of renewable energy is still low in the form of 4.54% (Hydro 2.54%, 2.01% excluding Hydro). In addition, considering the negative effects of fossil fuel use on the environment, the temperature change in the world increased by 131.6% in 2019 compared to 1990 (FAOSTAT, 2021) and the increases in temperature changes threaten hydro resources which have a 55.84% share among the world's renewable energy resources in 2018 IEA, 2021). In addition, while 2 billion tons of CO2 gas were released in the world at the beginning of the 1900s, CO2 gas emissions increased by about 1600% in 2018 to 36.2 billion tons (Gürler et al., 2020:30). In addition, the increase in the world's population by 43.83% in 2018 compared to 1990 further increases the need for energy (World Bank, 2021). In addition to all these negativities, fossil fuel reserve lifetimes are 51 years in oil, 53 years in natural gas, and 114 years in coal (ETKB, 2017:3). In addition, the fact that the efficiency experienced in oil, coal, gas, biomass, nuclear, and renewable energy inputs has a very low rate of 11% despite today's technologies shows that the importance of renewable energy use and the need to use it increase for all countries in the world (Gürler et al., 2020: 16).

This study aims to expand the literature investigating the effect of renewable energy use on economic growth for OECD countries. This study has many contributions to the literature. First, it is researched for OECD countries, which have more than half of the world's GDP. The second is the use of an appropriate cointegration test for the data used instead of traditional unit root and cointegration tests. Third, it allows heterogeneity with the panel methods used, as well as providing additional strength by combining cross-section and time series. The fourth is the use of capital and labor variables as well as the use of renewable energy. Finally, the obtained results are supported by hypotheses.

2. Model and Data

To empirically investigate the effect of renewable energy consumption on economic growth, the following model can be written:

$$lnGDP_{it} = \beta_{0i} + \beta_{1i}lnREN_{it} + \beta_{2i}lnCPTL_{it} + \beta_{3i}lnLBR_{it} + \varepsilon_{it} \quad (1)$$

$$i = 1, \ldots, N \; ; t = 1, \ldots, T$$

Where GDP, REN, CPTL and LBR stand for Real GDP, real gross fixed capital formation, labor force and renewable energy consumption, respectively.

For Australia, Austria, Belgium, Canada, Denmark, France, Germany, Iceland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and the United States 20 OECD countries Annual data covering the period 1990-2019 were used. Real GDP in constant 2010 US dollars, real gross fixed capital formation in constant 2010 US dollars, the labor force in millions, and renewable energy consumption in kilotonnes of oil equivalent as expected hydro (Solar PV, solar th, tide, wind, heat pump, boiler, chemistry heat, and energy generation from others). Real GDP, real gross fixed capital formation, and labor force data were obtained from the World Bank and renewable energy consumption data were obtained from the International Energy Agency (IEA). Natural logarithms of all variables were used.

3. Methods and Findings

In this study, three steps are used for the relationship between renewable energy and economic growth for OECD countries. First, panel unit root tests, then cointegration, and finally causality tests were used. The reason for using panel data is that it increases the statistical power of the tests by combining information in both cross-section and time dimensions. The analysis method used in this study is Apergis and Payne (2010a), Apergis and Payne (2010b), Apergis and Payne (2011a), Apergis and Payne (2011b), Agir et al. (2011), and Apergis and Payne (2012) studies are used as reference.

Unit Root Tests

For variables, Levin et al. (2002) (LLC) and Im et al.(2003) (IPS) stability tests were performed and the results are presented in Table 1. Variables have unit root results for both level and first difference:

Table 1. Panel unit root test

	lnGDP	ΔlnGDP	$lnREN$	$\Delta lnREN$	$lnCPTL$	$\Delta lnCPTL$	$lnLBR$	$\Delta lnLBR$
LLC	-5.54^{***} (0.000)	-11.90^{***} (0.000)	-4.07^{***} (0.000)	-11.17^{***} (0.000)	-2.21^{**} (0.014)	-14.24^{***} (0.000)	0.45 (0.672)	-11.05^{***} (0.000)
IPS	0.97 (0.833)	-12.25^{***} (0.000)	2.03 (0.979)	-10.98^{***} (0.000)	1.56 (0.941)	-13.60^{***} (0.000)	5.41 (0.999)	-12.36^{***} (0.000)

Note: Numbers in parentheses are p-values. Schwarz Bayesian Criterion was used to determine the optimal lag lengths. *** and ** indicate the statistical significance at 1 and 5 percent levels, respectively.

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When Table 1 is examined, Levin et al. (2002) (LLC) test results, while real GDP (lnGDP) and renewable energy consumption (lnREN) are stationary at a 1% significance level and real gross fixed capital formation (lnCPTL) is stationary at 5% significance level, while labor force (lnLBR) is stationary after taking the first difference becomes stationary. On the other hand, Im et al. According to (2003) (IPS) test results, all variables have unit roots in their level values. However, all variables become stationary at the 1% significance level after taking the first difference. When the results are evaluated as a whole, it can be said that all variables become stationary after the first difference is taken. Therefore, the degree of integration of each is I(1). These empirical results show that a cointegration relationship can be found between the variables and Pedroni cointegration tests can be used to investigate this relationship. Therefore, in the next step, the relationship between renewable energy consumption and economic growth in the relevant period for OECD countries will be investigated with current period data

Cointegration Tests

Pedroni (1999) and Pedroni (2004) are two cointegration tests. These tests include four statistics: Panel-V, Panel-ρ, panel PP and panel ADF. The purpose of these tests is to combine the autoregressive coefficients in different countries by applying the stationarity test for the residuals in the model. These tests take into account the heterogeneity of the units as well as the common time factors. For group tests, Panel-V, Panel-ρ, panel ADF statistics are taken into account. The main hypothesis here is that there is no cointegration. Table 2 reports the cointegration relationship between the variables. When Table 2 is examined, all test statistics except Group- ρ show that there is cointegration between renewable energy consumption and economic growth in the relevant period for OECD countries.

Table 2. Panel cointegration test

Within-dimensian tests		**Between-dimensian tests**	
Panel-V	5.41^{***}		
Panel-ρ	0.72	Group- ρ	1.83
Panel-PP	-1.93^{**}	Group -PP	-2.30^{**}
Panel-ADF	-2.35^{***}	Group -ADF	-3.86^{***}

Note: *** and ** indicate the statistical significance at 1 and 5 percent levels, respectively.

After the cointegration relationship is found, a cointegration coefficient estimation will be made. The cointegration coefficient estimations were made with the Fully Modified Ordinary Least Square (FMOLS) and Dynamic Ordinary Least Squares Method (DOLS) estimators developed by Pedroni (2000) and Pedroni (2001). FMOLS estimation $\hat{\beta}^{*}_{GFM} = N^{-1}\sum_{i=1}^{N}\beta^{*}_{FMi}$ where is β^{*}_{FMi} obtained from the time series FMOLS estimation of the equation (1) for each country. In the DOLS estimator, the model in the form of

$$lnGDP_{it} = \beta_{0i} + \beta_{1i} lnREN_{it} + \beta_{2i} lnCPTL_{it} + \beta_{3i} lnLBR_{it} + \sum_{k=-K_{ii}}^{K_{ii}} \omega_{ik} \Delta lnREN_{it} + \sum_{k=-K_{ii}}^{K_{ii}} \lambda_{ik} \Delta lnCPTL_{it} + \sum_{k=-K_{ii}}^{K_{ii}} \eta_{ik} \Delta lnLBR + \varepsilon_{it}^{*} \quad (2)$$

$$i = 1, 2, \dots, N \,;\, t = 1, 2, \dots, T$$

must be estimated by OLS for each country.

Where K_{ii} and $-K_{ii}$ are leads and lags. DOLS estimator can be constructed as $\hat{\beta}_{GD}^{*} = N^{-1} \sum_{i=1}^{N} \beta_{Di}^{*}$, where β_{Di}^{*} is obtained from the estimation of equation (2) (Ağır et al, 2011:452).

Table 3 shows that economic growth is positively related to renewable energy consumption, real gross fixed capital, and labor force in the long run. In addition, all coefficients are statistically significant at the 1 percent significance level. Since the variables have natural logarithms, they will be interpreted as elasticity coefficients

Table 3. Panel cointegration estimation

	Panel FMOLS	Panel DOLS
lnREN	0.069*** (0.014)	0.079*** (0.029)
lnCPTL	0.331*** (0.019)	0.347*** (0.033)
lnLBR	0.940*** (0.078)	0.838*** (0.140)

Note: Leads and lags were set to 1 for the panel DOLS estimator. *** denotes statistical significance at %1 level..

When Table 3 is examined, the magnitude and sign of all coefficients showed similar results according to both FMOLS and DOLS results. In addition, according to the results of both estimators, the labor force that increased the economic growth the most was found. Considering the coefficients, according to the FMOLS results, a 1% increase in the labor force causes an approximately 0.84% increase in economic growth. On the other hand, according to DOLS results, a 1% increase in the labor force causes an approximately 0.94% increase in economic growth. On the other hand, considering all variables, according to FMOLS results, a 1% increase in renewable energy consumption and real gross fixed capital increases economic growth by approximately 0.07% and 0.33%, respectively. On the other hand, according to DOLS results, a 1% increase in renewable energy consumption and real gross fixed capital increases economic growth by approximately 0.08% and 0.35%, respectively. Therefore, renewable energy consumption has a positive effect on economic growth for OECD countries in the relevant period.

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Causality Analysis

The cointegration relationship between the series can show that there is a causal relationship between the variables. Therefore, if the series has a cointegration relationship, in the long run, it should be estimated with a vector error correction model by extending the VAR model with a single-lagged error correction term. Therefore, the VECM model is

$$\Delta lnGDP_{it} = \delta_{1i} + \sum_{q=1}^{l} \delta_{11iq}\, \Delta lnGDP_{it-q} + \sum_{q=1}^{l} \delta_{12iq}\, \Delta lnREN_{it-q} + \sum_{q=1}^{l} \delta_{13iq}\, \Delta lnCPTL_{it-q} + \sum_{q=1}^{l} \delta_{14iq}\, \Delta lnLBR_{it-q} + \varphi_{1i}\hat{\varepsilon}_{it-1} + v_{1it}$$

$$\Delta lnREN_{it} = \delta_{2i} + \sum_{q=1}^{l} \delta_{21iq}\, \Delta lnREN_{it-q} + \sum_{q=1}^{l} \delta_{22iq}\, \Delta lnGDP_{it-q} + \sum_{q=1}^{l} \delta_{23iq}\, \Delta lnCPTL_{it-q} + \sum_{q=1}^{l} \delta_{24iq}\, \Delta lnLBR_{it-q} + \varphi_{2i}\hat{\varepsilon}_{it-1} + v_{2it}$$

$$\Delta lnCPTL_{it} = \delta_{3i} + \sum_{q=1}^{l} \delta_{31iq}\, \Delta lnCPTL_{it-q} + \sum_{q=1}^{l} \delta_{32iq}\, \Delta lnREN_{it-q} + \sum_{q=1}^{l} \delta_{33iq}\, \Delta lnGDP_{it-q} + \sum_{q=1}^{l} \delta_{34iq}\, \Delta lnLBR_{it-q} + \varphi_{3i}\hat{\varepsilon}_{it-1} + v_{3it}$$

$$\Delta lnLBR_{it} = \delta_{4i} + \sum_{q=1}^{l} \delta_{41iq}\, \Delta lnLBR_{it-q} + \sum_{q=1}^{l} \delta_{42iq}\, \Delta lnREN_{it-q} + \sum_{q=1}^{l} \delta_{43iq}\, \Delta lnCPTL_{it-q} + \sum_{q=1}^{l} \delta_{44iq}\, \Delta lnGDP_{it-q} + \varphi_{4i}\hat{\varepsilon}_{it-1} + v_{4it}$$

where l represents the optimal delay length, and epsilon represents the residues obtained from the FMOLS estimates of equation (1). These equations allow the identification of long- and short-run causality. When investigating short-run causality, a Wald test is applied with zero constraints on the parameters of the first-differenced variables. When investigating long-term causality, the t-statistic of error correction coefficients (φ) is examined with statistically negative and significant significance.

The Granger causality test results between the variables were calculated and shown in Table 4 for both short and long term

Table 41. Granger Causality

	Short-run causality				Long-run causality
	$\Delta lnGDP$	$\Delta lnREN$	$\Delta lnCPTL$	$\Delta lnLBR$	ECT
$\Delta lnGDP$		4.29(0.0384)	6.73(0.0095)	3.76(0.0527)	-0.133**

$\Delta lnREN$	2.65(0.1033)		1.06(0.3026)	0.01(0.9347)	5.173
$\Delta lnCPTL$	2.35(0.1257)	4.67(0.0308)		0.08(0.7839)	0.496
$\Delta lnLBR$	2.00(0.1570)	3.52(0.0607)	20.93(0.0000)		0.047**

Note: The p-values are in parentheses. ** indicate the statistical significance at 5% levels.

When Table 4 is analyzed, it is pointed out that there is a short-term unidirectional causality running in the long run from renewable energy consumption, real gross fixed capital and labor force to economic growth. In addition, there is unidirectional causality running from renewable energy consumption to real gross fixed capital in the short run. On the other hand, it indicates short-run unidirectional causality running in the long run from renewable energy consumption and real gross fixed capital to labor force. Therefore, the growth hypothesis is valid for OECD countries, since there is a long-run short-run unidirectional causality running from renewable energy consumption to economic growth

4. Conclusions and Policy Implications

In this study, the relationship between renewable energy consumption and economic growth for 20 OECD countries, which have 55% of the world GDP as of 2018, is discussed. The difference of this study from other studies is that more observations, calculation techniques, and hydro resources are added to renewable energy consumption, including recent periods with current period data. Therefore, these situations make the results obtained from this study wider, more consistent, and healthier. LLC and IPS unit root tests, Pedroni cointegration, and Granger causality tests were used for the analysis. First of all, stationarity tests were performed and it was shown that the series were stationary at the first difference. After taking the first difference of all variables, the Pedroni cointegration test was applied with the thought that a cointegration relationship could be found and a cointegration relationship was found. Finally, the Granger causality test was applied for the variables with a long-term relationship. The results show that increases in renewable energy consumption support the growth hypothesis that economic growth will increase. Therefore, negative effects such as tax increases and bureaucratic obstacles to be applied on renewable energy in the relevant period for OECD countries will cause the welfare of these countries to be negatively affected.

The share of renewable energy (including hydro) consumption in total energy consumption in OECD countries in 2018 has a low rate of 5.14%. However, although this rate was well below the desired level, it had a lower share of 2.98% in 1990. Therefore, almost doubling of this rate indicates that incentive policies are implemented in the field of renewable energy. In addition, fossil fuels had an annual increase rate of 0.18% in 1990-2018, while renewable energy had an annual increase rate of 2.37%. Therefore, although the share of renewable energy use in OECD countries is not at the desired level, the average rate of increase is increasing and this situation has a positive effect on the welfare level.

All of the suggested factors were found to be consistent with the predicted parameters, models-techniques, and meet theoretical expectations. The model in which all variables were found to be significant could be estimated. Increases in renewable energy consumption, real gross fixed capital formation, and labor force positively affect economic growth. As a result, all of the variables put forward to have a positive effect on economic growth. Findings obtained in this study Apergis and Payne (2010), Chen et al. (2020), Ohler and Fetters (2014), Lin and Moubarak (2014), and Chang et al. (2015) coincides with the findings of the study.

In the light of the results obtained in the study, policymakers have important duties for the OECD countries included in the analysis. These; Policies to reduce installation costs, which are very important for renewable energy needed for sustainable growth, can be implemented, R&D activities can be increased, equipment to be used in the field of renewable energy can be produced locally, financing or credit facility can be provided in the field of renewable energy, tax reduction in the field of renewable energy or subsidies with tax exemptions can be granted, new buildings or business centers can be constructed to use renewable energy, conditions for the transmission, transport, and storage of energy from renewable energy can be improved, renewable energy use lands can be increased, bureaucratic barriers reduced, and education and training People can be made conscious with informative messages in the field of edible energy on social networking sites (Durğun and Durğun, 2018: 23). In other words, countries will be able to reduce foreign dependency on energy by meeting the energy they need with their own resources through the use of renewable energy. Therefore, governments need to create policies on energy with incentives, deterrent laws, sanctions, inspections, measures, accurate information, and training for the use of renewable energy, where it is important to switch to domestic energy.

Considering the limitations of the study, the relationship between renewable energy consumption and economic growth has been investigated, regardless of energy importing or energy-exporting countries or developed and developing country groups. In addition, renewable energy consumption hydro and wind, solar, etc. Indiscriminately, the relationship between total renewable energy consumption and economic growth has been investigated.

For research following this study, the relationship between renewable energy consumption and economic growth can be investigated in particular for countries that are divided into groups as energy importers and exporters. In addition, the relationship between renewable energy consumption and economic growth can be investigated for developed and developing country groups with current period data. In addition to investigating the relationship between renewable energy consumption and economic growth at the general economy level for a certain country group, it is thought that researching this relationship in sectoral terms will make very important contributions to the literature.

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