Sosyoekonomi

2024, Vol. 32(60), 95-109

RESEARCH ARTICLE

ISSN: 1305-5577
DOI: 10.17233/sosyoekonomi.2024.02.05
Date Submitted: 04.06.2023
Date Revised: 17.01.2024
Date Accepted: 23.02.2024

Solar Energy Production and Economic Growth: An Analysis for EU Countries

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Güneş Enerjisi Üretimi ve Ekonomik Büyüme: AB Üyesi Ülkeler İçin Bir İnceleme

Abstract

Producing and consuming solar energy as a clean energy resource in economies has gained importance. The importance of solar energy is based on reducing costs due to technological developments. Responsive to whether the contribution of investing in solar energy to reach proclaimed new development strategies in the EU Green Deal has been one of the critical indicators for policymakers nowadays. In this context, this paper analysed the impacts of solar energy production on the economic growth of EU member countries. After the analysis, using a two-way fixed effects model and Driscoll-Kraay standard errors 2018-2021, solar energy production's positive and statistically significant effects on economic growth were found.

Keywords : Solar Energy, Economic Growth, EU Economies, Green Economy, European Green Deal.

JEL Classification Codes : Q2, Q5.

Öz

Temiz bir enerji kaynağı olarak güneş enerjisinin kullanımı ve güneş enerjisinin ekonomiler üzerindeki etkisi gün geçtikçe artmaktadır. Bu artışı belirleyen temel faktör ise son yıllarda gelişen teknoloji ile birlikte güneş enerjisinin maliyetlerinde gerçekleşen belirgin düşüştür. Güneş enerjisinin Avrupa Yeşil Mutabakatında açıklanan yeni büyüme stratejisine katkı sağlayıp sağlamayacağı politika yapıcıların cevap bulmaya çalıştığı soruların başında gelmektedir. Bu bağlamda çalışmada AB üyesi ülkelerde güneş enerjisi üretiminin ekonomik büyüme üzerindeki etkisi incelenmiştir. 2018-2021 döneminin iki-yönlü sabit etkiler modeli ve Driscoll-Kraay standart hataları ile ele alındığı çalışmada, güneş enerjisi üretiminin ekonomik büyüme üzerinde pozitif ve istatiksel olarak anlamlı bir etkisi olduğu sonucuna ulaşılmıştır.

Anahtar Sözcükler : Güneş Enerjisi, Ekonomik Büyüme, AB Ekonomileri, Yeşil Ekonomi, Avrupa Yeşil Mutabakatı.

1. Introduction

Energy sources are one of the main inputs for realising economic development targets. Nevertheless, non-renewable energy sources damage the environment and cause global climate change. The damage caused by global climate changes to national economies has resulted in a profound revision of development policies. The EU took the first concrete initiative through the European Green Deal, which was approved in December 2019 and proclaimed that it would adopt a new economic development policy to prevent the developmental issues of global climate change (European Commission, 2019). Following the recent economic growth strategy, the EU has confirmed that the targets of Europe will be reaching the first climate-neutral continent by 2050 and reducing carbon emissions by a minimum of 55% in 2030 compared to the 1990s. The new environment-friendly development targets of the EU have become binding for member countries since the enactment of the European Climate Law in July 2021(European Commission, 2021).

The member countries have become more interested in renewable energy sources to achieve the EU's targets. The main factor in using renewable energy sources is the cost of these sources. One of the renewable energy sources, solar energy cost, especially in PV (solar PV), has been consistently reducing since the beginning of the 2010s (Kougias et al., 2021: 2). These cost advantages have made solar energy more strategic than ever. Thus, solar PV products reached the highest growth rate between 2013 and 2020 (Al-Shetwi, 2021: 6). In 2019, solar and wind energy sources reached the most increased new energy production for the first time worldwide (European Commission, 2020: 5). While solar PV constituted 43% of renewable energy investments in 2020, wind energy accounted for 47% (IRENA, 2023: 15). In 2021, solar PV and wind energy continued to be the dominant new renewable energy investments, and the sharing of solar PV and wind energy constituted 56% and 40% of the all-new renewable energy investments. Moreover, more than 10% of global electricity production will come from solar and wind energy sources in 2021 (REN21, 2022: 175). Specifically, in the EU, photovoltaic energy has been the second most growing renewable energy source after wind energy (Wolniak & Skotnicka-Zasadzien, 2022: 5). As Borawkski et al. (2022) indicated, solar energy will catalyse the growth of renewable energy sources. In this context, although Germany has been a leader in the solar installed capacity among EU member countries, the share of other members has steadily been rising. The same growth trends may be observable in the share of solar energy sources in electricity production in EU member countries (European Commission, 2022).

The evaluation of the role of solar energy looks inevitable because of its growing importance worldwide, specifically in EU countries. The primary objective of this paper is to explore the potential contribution of solar energy production to the economic growth of EU countries within this context. Accomplishing this has the potential to make a meaningful impact on the current literature in three distinct ways. Firstly, it has the potential to contribute to the ongoing discussions regarding integrating solar energy into the economic growth strategy of the European Green Deal. Secondly, the European Green Deal has developed as a policy goal to achieve climate neutrality throughout the continent by 2050. Assessing solar energy's impact on economic growth as a renewable energy source is essential for realising this policy implication. The findings could prove beneficial for policymakers and practitioners in shaping policy priorities. Finally, and in conclusion, despite the increasing body of literature regarding the relationship between renewable energy and economic growth, there remains a scarcity of comprehensive research examining the impact of solar energy generation on economic growth. This study tries to fill this gap and speculate the research relationship between solar energy and economic growth. To achieve this, the effect of solar energy production on economic growth will be analysed with a two-way fixed effects model and Driscroll-Kraay standard errors for EU member countries in 2018-2021.

This paper is organised as follows: The next part focuses on the debates in the existing literature. The third part gives details on the data set and methods. The fourth section interprets the empirical results of the analysis. Finally, a general evaluation will be made in the conclusion section.

2. Literature Review

After the sharp decline in production costs, the share of solar energy sources has increased in total renewable energy resources (Kabir et al., 2018: 898). This increase in solar-based energy has made investigating the relationship between solar energy and economic growth inevitable. Although the need to understand this relationship is critical, research is rarer than studies of renewable energy and economic growth. Despite the increasing number of studies addressing the relationship between renewable energy and economic growth for developed economies (Payne, 2009; Tugcu et al., 2012; Chang et al., 2015; Rafindadi & Ozturk, 2017; Behera & Mishra, 2020; Filiz-Baştürk, 2021), and developing economies (Sadorsky, 2009; Apergis & Payne, 2011a; Ocal & Aslan, 2013; Pau & Fu, 2013; Lin & Moubarak, 2014; Ozcan & Ozturk, 2019; Azam et al., 2021; Filiz Baştürk, 2022), separately and examining this relationship together for both country groups (Apergis & Payne, 2011b; Singh et al., 2019; Polat, 2021) they have yet to conclude common results. These reverse results in the literature are mainly due to differences between the covered periods, selected countries or groups, and set econometric methods (Ozturk, 2010).

As an illustration, Payne (2009) analysed the long-run relationships within developed economies, specifically focusing on the period from 1949 to 2006 for US data. The Toda-Yamamoto causality test was utilised in this study to assess the linkage between renewable-non-renewable energy consumption and economic growth. The Toda-Yamamoto causality test revealed no Granger causality association between renewable energy consumption and real GDP. The findings confirmed the neutrality hypothesis. Furthermore, Tugcu et al. (2012) examined the period from 1980 to 2009 in the G7 nations. Their investigation revealed a bidirectional causality between renewable energy consumption and economic growth based on the assumption of utilising the classical production function. Chang et al. (2015) conducted a study analysing renewable energy consumption and economic growth from 1990-2013, providing another example of a subject of G7 countries analysis. The results of this study demonstrate a causality between renewable energy consumption and economic growth for all panels. A country-specific analysis confirmed the neutrality hypothesis for Germany, Italy, the US, and the UK. However, causality was found between renewable energy consumption and economic growth in France, Canada, and Japan. The research conducted by Rafinaldi and Ozturk (2017) investigated German quarterly data from 1971 to 2013. The findings revealed that a 1% increase in renewable energy consumption resulted in a 0.2194% boost in economic growth. In their study, Behera & Mishra (2020) examined the relationship between economic growth and non-renewable and renewable energy consumption in G7 countries. The analysis utilised data from the period 1990-2015. The results of their research present findings that contradict those mentioned in previous studies, indicating a negative impact of renewable energy consumption on economic growth after analysis. The research conducted by Filiz Baştürk (2021) yielded yet another contradictory outcome concerning the relationship between renewable energy consumption and economic growth. The study found no long-run relationship between these variables based on data from 1990-2017 for G7 countries.

Additionally, the literature consists of studies exploring developing nations' cases. According to Sadorsky's (2009) study, which analysed generalised data from developing countries, a 1% increase in real GDP per capita led to a 3.5% increase in renewable energy consumption per capita in the long run. In a separate study, Apergis and Payne (2011a) analysed data from 1990-2007 to examine the relationship between non-renewable and renewable electricity consumption and economic growth in 16 emerging markets. The findings of their study indicate a causality relationship between economic growth and renewable electricity consumption in the short run, whereas analysis reveals a bidirectional causality between the two variables in the long run. Also, Ocal & Aslan (2013) employed Türkiye-specific data from 1990-2010 to examine the causal relationship between renewable energy consumption and economic growth. The research findings suggest causality from economic growth to renewable energy consumption. The study conducted by Pao & Fu (2013) examined data from Brazil. Their research determined that a 1% rise in renewable energy consumption resulted in a 0.20% increase in economic growth. In their study, Lin and Moubarak (2014) found evidence of a bidirectional causality between renewable energy consumption and economic growth in China from 1977 to 2011. Ozcan & Ozcan's (2019) investigation relied on cross-country data encompassing 17 emerging markets from 1990 to 2016. The primary focus was to explore the association between renewable energy consumption and economic growth. The results of their research validated the neutrality hypothesis for all countries in the sample, apart from Poland. Moreover, the findings from the Polish data align closely with the arguments presented by the growth hypothesis. Azam et al. (2021) study has pointed out different aspects of investigating the relationship between renewable electricity generation and economic growth, and their analysis confirmed the feedback hypothesis by detecting bidirectional causality between variables in both short-run and long-run for 25 developing countries' data from 1990 to 2017 period. In her study, Filiz Baştürk (2022) examined the relationship between renewable energy consumption and economic growth among five emerging markets, Türkiye, Brazil, China, India, and Mexico, from 1995-2007. The analysis confirmed the feedback hypothesis for Türkiye, China, and Mexico while validating the neutrality hypothesis for Brazil and India.

Moreover, a body of literature analysed the link between renewable energy consumption and economic growth in developed and developing economies. One of the studies that examined the connections between non-renewable and renewable energy consumption and economic growth for developed and developing economies from 1990 to 2017 is Aspergis & Payne's (2011b) research. The analysis concluded that bidirectional causality existed between variables in the short and long run. Another study examining the relationship between renewable energy production and economic growth in developed and developing countries is by Singh, Nyuur, and Richmond (2019). In this study, which covers the period 1995-2016, it is stated that renewable energy production affects positive and statistically significant economic growth for both country groups. According to Polat's (2021) work, the analysis confirmed the neutrality hypothesis between renewable energy consumption and economic growth for both groups of countries.

These confusing results can be found in studies on EU member countries. For example, Smolovic et al. (2020) divided all member countries into two groups, as new and former members. They found positive and statistically significant effects between renewable energy consumption and economic growth for both groups in the long run. Similarly, Armenau et al. (2017) claimed that primary renewable energy production positively affected GDP per capita for EU-28 countries. However, research by Menegaki (2011) did not find any granger causal relationship between renewable energy consumption and economic growth in 27 EU member countries. Also, Marques and Fuinhas (2012) indicated completely disparate conclusions and found negative effects of renewable energy sources on economic growth in 24 EU members. They explained these negative effects by the high-level opportunity costs of renewable energy subsidies. They also highlighted in their research conclusion the role of political justification rather than economic ones in the decision to develop renewable energy. This result may not be a surprise because the decline in wind and solar energy production costs started after 2010.

After the beginning of the sharp cost decline period in 2010, studies on the interactions between solar energy and economic growth have gained more importance. However, a few research studies have been done in the literature. Only limited-time relevant data could be available in many countries, which has been the main obstacle to the deepening of literature. On the other hand, simultaneously enriched available data sources and increasing solar energy investment will redound the rising number of quantitative and qualitatively convincing studies.

Like the confusing results of studies on renewable energy and economic growth, the studies specifically focused on solar energy on economic growth have not reached precise conclusions. For example, in a study focused on the impact of each renewable energy source on economic growth in EU countries, Busu (2020) found that each energy source (solar, wind, biomass, geothermal, and hydropower) positively affected economic growth.

However, Jaraite et al. (2017) used data from EU-15 countries and confirmed the positive impacts of solar and wind energy production on economic growth. However, this relationship was only possible in the short run, and the effects had yet to stimulate economic growth. Other research by Bulut and Apergis (2021) used US data for the 1984-2018 periods and centred on the impacts of solar energy consumption on GDP. Their analysis confirmed the statistically significant and positive relationship between solar energy consumption and economic growth. In his study, Koç (2021) reached the growth hypothesis about solar energy use impacts on economic growth, which covered 19 countries. Further, Yang and Kim (2020) examined a different point of view. They handled the relationship between producing electric energy from renewable sources and economic growth within the firm-based analysis. They generated two country groups for research: one cluster of countries based on solar PV producers' firms and the other on wind energy producers' firms. After the analysis, they found evidence of the growth hypothesis for Canada, the conservative hypothesis for China, and the feedback hypothesis for the US and Korea.

Additionally, some studies have shown that solar energy has a non-significant impact on economic growth. For instance, Ohler and Fetters (2014) examined the relationship between electricity generation from renewable energy sources and economic growth in 20 OECD countries. They found a one-way relationship between solar energy production and economic growth. The direction of the relationship was from economic growth to solar energy production. Bulut and Menegaki (2020) investigated the relationship between solar energy production and economic growth for ten countries with the highest solar power generation capacity as of 2017. They found statistically non-significant impacts of solar energy production on economic growth from 1999-2015. Their results showed no causal relationship between the two variables and confirmed the neutrality hypothesis. Similarly, Topcu and Dogan (2022) examined 11 leading countries in solar energy production and concluded that solar energy production was no effect on economic growth. When they looked at the causality relationship between the variables, they found a causality from economic growth to solar energy production.

Tablo: 1
Literature Review of Solar Energy and Economic Growth

Author(s)	Countries	Period	Methodology	Results
Ohler & Fetters (2014)	20 OECD Members	1990-2008	Panel ECM	Unidirectional relationship from economic growth to solar electricity generation
Jaraite et al. (2017)	15 EU Members	1990-2013	Panel ECM	Solar energy production affects economic growth in the short run, but not in the long run.
Busu (2020)	European Union	2004-2017	Panel ARDL	Solar energy production has a positive effect on economic growth
Bulut & Menegaki (2020)	Top 10 Countries	1999-2015	Panel Cointegration	Solar energy production does not affect GDP and has no causal relationship exists between solar energy production and GDP
Bulut & Apergis (2021)	USA	1984-2018	Cointegration	Solar energy consumption has a positive effect on the GDP
Koç (2021)	19 Countries	1990-2019	Fixed Effect, Random Effect, GMM	Solar energy use has a positive effect on the GDP
Topcu & Dogan (2022)	11 Leading Countries	2000-2019	Dynamic SUR	Solar energy production does not affect economic growth; unidirectional causality runs from economic growth to solar energy production.

Eventually, the limited number of studies in the literature have no consensus, and these studies have indicated different types of relationships between solar energy and economic growth. Table 1 highlights studies in the literature examining the relationship between solar energy and economic growth.

3. Data and Methodology

3.1. Data Set and Model Variables

Table 2 shows the variables and data sources used for this paper. The natural logarithm was used for all variables in the predicted model, and the analysis was made in Stata 16.0. The model used real GDP (constant 2015 US$) to show economic growth. It also used the total labour force as the labour force and gross fixed capital formation (constant 2015 US$) as the capital. Solar energy production data was derived from BP (2022). World Development Indicator data set from the World Bank (2022) used for real GDP, capital, and labour.

Table: 2
Definitions of Used Variables in the Analysis

Variables	Symbol	Source
Solar production (GWh)	lnsolar	BP Statistical Review of World Energy- all data, 1965-2021
Real GDP (constant 2015US$)	lnY	World Development Indicators (World Bank)
Labor force	lnL	World Development Indicators (World Bank)
Gross fixed capital formation (constant 2015 US$)	lnK	World Development Indicators (World Bank)

3.2. Model Specification

This paper examined the impact of solar energy on the economic growth of 26 EU member countries (the analysis did not include Malta's solar generation/production data because it was unavailable) by production function for the 2018-2021 period. Lutkephol (1982) warned of the possibility of omitted variables for two-variable analysis. The study used labour and capital variables to eliminate the risk of omitted variables (Payne, 2010: 730). The production function used in this paper is as follows:

$$Y = f(\text{solar}, L, K) \quad (1)$$

The log-linear model estimated in the study is as follows:

$$\ln Y_{i,t} = \alpha_0 + \beta_1 \ln solar_{i,t} + \beta_2 \ln L_{i,t} + \beta_3 \ln K_{i,t} + e_{i,t} \quad (2)$$

The *i* symbol indicates the country; also, *t* shows the period. α_0 is used to express the constant term. β_1, β_2, and β_3 represent solar, labour, and capital elasticity for output, respectively. Finally, e shows as the error term.

The hypothesis that was tested for analysis is as follows;

Hypothesis: Solar energy production has had a positive impact on economic growth.

3.3. Estimation Method

Panel data is characterised by the inclusion of cross-sectional data along with a time dimension. The standard representation of the panel data model is as follows (Yerdelen-Tatoğlu, 2018: 4):

$$Y_{it} = a_{it} + \beta_{it} X_{it} + u_{it} \qquad i=1,\ldots,N; \qquad t=1,\ldots,T \qquad (3)$$

Here i: shows cross-section; t: shows time dimension; Y: shows dependent variable; X_k: independent variables; α: fixed parameter; β: slope parameters and u means error term. In most panel data applications, a one-way error component model addresses disturbances (Baltagi, 2013: 13).

$$u_{it} = \mu_i + v_{it} \qquad (4)$$

In here μ_i: shows the unobservable individual-specific effect and v_{it}: remainder disturbance.

The fixed effect model is estimated as one-way and two-way (Torres-Reyna, 2007: 18-19). In the one-way fixed effects model, μ_i are considered the fixed parameters that need to be estimated. It is assumed that the remaining disturbances v_{it} follow a stochastic, independent, and identically distributed IID (0, σ_v^2) (Baltagi, 2013: 14). As stated by Baltagi (2013: 14), it is postulated that X_{it} assumed to be independent of v_{it} for all i and t.

If we take into account Equation-3 as disturbances involving a two-way error component (Baltagi, 2013: 39);

$$u_{it} = \mu_i + \delta_t + v_{it} \qquad (i=1,\ldots,N;\ t=1,\ldots,T) \qquad (5)$$

In here μ_i: shows the unobservable individual effect, δ_t: unobservable time effect, v_{it}: remainder stochastic disturbance term. Also δ_t, individual-invariant and time-specific effects that are not accounted for in the regression are considered. Given that μ_i and $\delta_t$are the parameters to be estimated, and the disturbance v_{it} ~ IID (0, σ_v^2) are stochastic, equation 5 can be seen as the error component model with two-way fixed effects. For all i and t, it is assumed that $X_{it}$is independent of v_{it} (Baltagi, 2013: 39).

Generally speaking, it can be expressed in the following manner. Only individual-specific variables could be included in a one-way fixed effects model. In contrast, it could be possible for both individual-specific and time-specific variables to enter into a two-way fixed effects model (Greene, 2002: 336). Equation (6) contains the one-way fixed effects model, and equation (7) shows the two-way fixed effects model (Baltagi, 2013: 15-40; Torres-Reyna, 2007: 18-19).

One-way fixed effects model:

$$Y_{it} = (a_i + \mu_i) + \beta X_{it} + v_{it} \qquad i = 1\ldots n,\ T = 1\ldots T \qquad (6)$$

Two-way fixed effects model:

$$Y_{it} = (a_i + \mu_i + \delta_t) + \beta X_{it} + v_{it} \quad i = 1 \ldots n,\ T = 1 \ldots .. T \tag{7}$$

where:

Y_{it} : outcome variable

a_i : is the intercept term

X_{it} : is a vector of predictors

μ_i: unobservable individual-specific effect

δ_t : unobserveble time specific effect

v_{it} : (v_{it} ~ IID (0, σ_v^2))

β: model coefficients

In this paper, an estimation of the impacts of solar energy on economic growth is made using the fixed effects model for 26 EU member countries. Baltagi (2013: 14) indicated that the fixed effects model is an appropriate framework for searching specific N group situations, such as in EU or OECD member countries.

4. Empirical Results

Panel data analysis has problems with heteroskedasticity, cross-sectional dependence, and autocorrelation. These problems may occur individually, doubled, or all during estimation. These assumption violation problems of panel data analysis may create misleading outcomes (Croutzet & Dabbous, 2021: 1613; Dabbous & Tarhini, 2021: 63). Accordingly, autocorrelation, heteroscedasticity, and cross-sectional dependence were checked respectively in predicting the fixed effects model to avoid assumption violation problems. Firstly, Wooldridge's (2002) test was used to check the analysis's autocorrelation problem (AC). The results of the Wooldridge test (p-value = 0.211) confirmed as not a rejection of the $\boldsymbol{H_0}$ hypothesis ($\boldsymbol{H_0}$: no serial correlation). Secondly, Wald tests were used to check the heteroscedasticity problem (HC). After the outcomes of the modified Wald test results (p-value = 0.000), the $\boldsymbol{H_0}$ hypothesis was rejected ($\boldsymbol{H_0}$: no heteroscedasticity). This means heteroscedasticity according to cross-units. The Pesaran CD (2015) test was used to control cross-sectional dependence. Test results (p-value = 0.000) showed that the $\boldsymbol{H_0}$ hypothesis ($\boldsymbol{H_0}$: no cross-sectional dependence) was rejected, and the correlation between cross-units exists.

For decision-making, whether a model used in this paper is fit controlled via two tests, as in Dabbous and Tarhini (2021). First, the F-test allowed the choice between the pooled OLS and the fixed-effects model. Then, Hausman's (1978) test decided whether fixed effects or random effects were valid. However, some details should be considered; the Hausman test is invalid in heteroskedasticity and autocorrelation problems. In that case, the robust Hausman test should be performed. For this reason, a robust Hausman test was performed because the model had an HC problem. According to the robust Hausman test result (p-value= 0.010), using the fixed-effects model was appropriate. Consistent with the robust Hausman test, the F test results (F (25,75) =105.12 and p-value=0.000) verify that the fixed-effects model fits the analysis.

The utilisation of a two-way fixed effects model was necessitated in this study by the COVID-19 pandemic. The two-way fixed effects model was predicted because time dummy variables are significant. The collective significance level of used time dummies was tested via a joint-F test. The test outcomes (p-value=0.000) confirmed that used time dummies have a collective significance level. Moreover, each time dummies have an individual significance level. After predicting the two-way fixed effects model, a control test was performed to determine whether existing HC and CD problems were still valid. While HC problems still occur according to the Modified Wald test outcome (p-value = 0.000), results of the Pesaran CD (2015) test (p-value = 0.812) showed eliminated CD problems. To adjust the HC problem, a two-way fixed effects model was estimated to be robust to HC. In addition, the two-way fixed effects model was estimated with Driscoll-Kraay's (1998) standard errors, which are robust to HC, AC, and CD problems, as Hoechle (2007) recommended. Estimation outcomes are shown in Table 3.

Table: 3
Regression Results

Dependent Variable: lnY	**Fixed Effect (One-Way)**	**Fixed Effect (Two-Way)**	**Fixed Effect (Two-Way) Robust**	**Fixed Effect (Two-Way) Driscoll-Kraay**
lnsolar	0.018** (0.008)	0.024*** (0.008)	0.024* (0.012)	0.024*** (0.002)
lnL	0.718*** (0.252)	0.418** (0.187)	0.418* (0.221)	0.418* (0.154)
lnK	0.054 (0.044)	-0.012 (0.034)	-0.012 (0.065)	-0.012 (0.053)
Constant	13.710*** (4.041)	19.883*** (3.046)	19.883*** (2.929)	19.883** (3.496)
Year Dummies				
2019		0.020*** (0.007)	0.020*** (0.004)	0.020** (0.004)
2020		-0.031*** (0.008)	-0.031*** (0.008)	-0.031*** (0.001)
2021		0.020** (0.009)	0.020* (0.010)	0.020** (0.003)
F statistics	105.12*** [0.000]			
Wooldridge AC Test	1.646 [0.211]			
Modified Wald Test	387.34*** [0.000]	9237.25*** [0.000]		
Pesaran CD Test	23.393*** [0.000]	-0.238 [0.812]		
Robust Hausman Test	[0.010]			
Observations	104	104	104	104
Number of Countries	26	26	26	26

*Notes: Standard errors are in parentheses. The values in square parentheses are the probability values of the coefficient. *** p < 0.01, ** p < 0.05, * p < 0.10.*

Obtained coefficients may be interpreted as elasticity estimates because all variables were shown as natural logarithms (Apergis & Payne, 2010: 658). According to the two-way fixed effects model result, a 1% rise in solar energy production increased economic growth by 0.024%, as shown in Table 3. The impact of solar energy production on economic growth was positive and statistically significant in the model. This study's findings support the notion that solar energy could contribute to achieving the policy objectives outlined in the European Green Deal's new growth strategy. In addition, these findings can be understood as EU member countries' solar energy investments reflecting coherent policy justifications. Moreover, the beneficial consequences of solar energy on economic growth ensure the security of the energy supply. The potential benefits discussed in this context can bolster the credibility of renewable energy-based policies for policymakers and practitioners.

The outcomes of this analysis are similar to other studies, although there is no consensus in the literature. For instance, Busu (2020) found that solar energy production had a 0.007 positive impact on the GDP of 28 EU member countries. For US data, Bulut and Apergis (2021) also concluded that solar energy consumption increased by 0.009 of economic growth. Koç's (2021) analysis focused on data from 19 countries and found that solar energy consumption increased economic growth by 0.07 for the random effect model and 0.006 for the GMM model. Although Ohler and Fetters's (2014) studies found a unidirectional causality relationship between economic growth and solar electricity generation, results confirmed the positive impacts of a 1% increase in solar energy generation has increased economic growth by 0.055%.

5. Conclusion and Policy Implications

Environmental issues related to climate change and the effects of global warming have become a tremendous hurdle for contemporary economies. Many economies have configured some policy targets to cope with these problems. In this context, the EU has set a target to be the first climate-neutral continent in the world until 2050, according to their policy aims, which included being the global policy leader in reducing climate change risks. Renewable energy resources are vital to new growth strategies for reaching climate change-reduced policy targets. Solar and wind energy have been gaining importance because of the recent reduction in costs within renewable energy resources. Specifically, solar energy as a clean energy resource has begun to be considered a priority after striking cost reduction due to the development of more effective production technology.

This paper has aimed to test these priorities for 26 EU member countries by evaluating the impacts of solar energy production on economic growth for 2018-2021. After the analysis, which used a two-way fixed effects model and Driscoll-Kraay standard errors, it has been found that solar energy production has positive and statistically significant effects on economic growth. These outcomes of analysis have been some hints for policymakers. Firstly, it has been implied that solar energy investments made by EU countries have been policy-rational due to the positive impacts of solar energy production on economic growth. Secondly, it has hinted that increasing solar energy investment will support reaching

European Green Deal targets for EU member countries. Finally, these analysis outcomes may present some positive arguments to policymakers for encouraging the continuation of regulative and incentive policies for solar energy investment so as not to lose momentum.

Although some studies in the literature have similar outcomes (for example, Busu (2020), Bulut and Apergis (2021), Koç (2021)), some others are in different directions (for example, Bulut and Menegaki (2020), Topçu and Doğan (2022), Ohler and Fetters (2014)). There has yet to be any consensus in the literature about the impacts of solar energy on economic growth. Multidirectional results in existing research in the literature have created some obstacles for policymakers to follow the optimal path. The policy-making process may be straightforward for investing in solar energy while enriching the research in the literature.

Like others in the literature, this paper has some limits. The first one is related to the cover of data. The analysis in this paper deals with 26 countries of 27 EU members because data on one member country (Malta) has not been available. Secondly, the study just looked at solar energy data. The potential impacts of other renewable energy resources were ignored in the research. Naturally, other renewable energy resources, such as wind energy, which is at least as important as solar energy for EU countries, should be analysed for impacts on economic growth.

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