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# The Role of Renewable Energy Generation in Sustainable Economic Growth: The Case of Turkey

**Ramazan ÖZBEK[1], Şükrü APAYDIN[2]**

**Abstract**

Energy is a crucial factor in both the production and consumption process. It is a critical component not only for economic growth but also for social, technological, and environmental issues. With the events and facts in these areas in the last fifty years, the importance of the energy factor has more increased, and the search for alternative energy sources has accelerated. Thus, renewable energy sources have started to be more preferred by considering sustainable growth goals. This study aims to investigate the role of renewable energy generation on economic growth for the period of 1990-2017. The study employs the Autoregressive Distributed Lag (ARDL) method by using gross domestic product, capital stock, employment, and renewable energy generation data of Turkey. According to the findings, increases in capital stock, employment, and renewable energy production affect economic growth positively.

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[1] Nevsehir Hacı Bektaş Veli University, Institute of Social Science, rozbek504@hotmail.com, https://orcid.org/0000-0003-0656-4520

[2] Nevsehir Hacı Bektaş Veli University, Faculty of Economics and Administrative Sciences, sukruapaydin@nevsehir.edu.tr, https://orcid.org/0000-0003-4640-8135

## 1. Introduction

Energy, such as labor and capital, is also the primary factor for economic growth. The reason for this, it is both an input and output of the production process. In other words, energy is both a production factor and an indicator of the level of welfare in the consumption (Organisation for Economic Cooperation and Development [OECD], 2006; Bruns, 2012). In the last quarter of the twentieth century, especially, energy factor has become one of the most critical components of modern economies as a result of events and facts such as the 1973-1974 oil crisis, rapid increases in the world population, urbanization, technological advances, climate change, and pollution (Berndt and Wood, 1975; Paul and Bhattacharya, 2004; Stern and Cleveland, 2004; Samuel, et al. 2013; Bektaş and Ursavaş, 2019) . In parallel, renewable energy has begun to be evaluated in the context of sustainable economic growth and development and has accelerated the search for alternative energy sources. As a result, all countries in the world have started to focus on renewable energy to achieve sustainable economic growth, and renewable energy generation has gradually increased over time. Table 1 summarizes the production of renewable energy in the world and Turkey.

**Table 1: Renewable Energy Generation in the World and Turkey (1965-2018 Period)**

| | World | | Turkey | |
|---|---|---|---|---|
| | Generation (Twh) | Growth Rate (%) | Generation (Twh) | Growth Rate (%) |
| 1965-2019 | 414,6 | 9,9 | 3,7 | 27,8 |
| *1965-1979* | 30,4 | 7,0 | 0,2 | 4,8 |
| *1980-1999* | 115,4 | 7,6 | 0,1 | 37,9 |
| *2000-2009* | 374,6 | 12,3 | 0,5 | 33,2 |
| *2010-2019* | 1629,3 | 16,0 | 19,1 | 36,3 |

*Notes:* Calculations were made by the authors. Generation quantities and growth rates show the average of the period. Twh: Terawatt-hours.
*Source:* BP (2020).

As can be seen from the table, in the 1965-2019 period, renewable energy production is 414,6 terawatt-hours on average, and the average rate of increase during the period is about 10 percent. The average growth rate of energy production was over 10 percent in the post-2000 period, while it remained at 7 percent on average during the period before 2000. The production amount, which was 115.4 terawatt-hours in the 1980-1999 sub-period, was 374.6 terawatt-hours in the 2000-2009 period and approximately 1630 terawatt-hours after 2010. In other words, awareness of renewable energy has increased worldwide after 1980 and has become more evident in the twenty-first century. A similar situation, especially for the period after 2010, is also the case for Turkey. An average of 19.1 terawatt-hours of renewable energy production in the period 2010-2019 is more than that of all previous periods, and the rate of increase in the period is around 36 percent. In short, there have been remarkable increases in renewable energy production both in the world and in Turkey, especially in the recent period. In this context, it will be crucial to determine how renewable energy production contributes to sustainable economic growth or whether it provides the expected contribution.

Therefore, the paper aims to identify the role of renewable energy production in sustainable economic growth by using the data of Turkey between 1991 and 2017 and the ARDL method. The main reason for choosing this method is to determine both the short-run and long-run effects of renewable energy generation on economic growth at the same time. Considering the method used and the variables analyzed, the main difference and the contribution of the study is that this study focuses on the effects of renewable energy production on growth rather than renewable energy consumption. Besides, this paper uses the Cobb-Douglas production function, which includes labor, capital, and renewable energy generation. In other words, the energy factor affecting economic growth, such as labor and capital, has been not neglected. Another difference in the study is that it covers only the Turkish economy, starting from the idea that each country has its conditions. Given these differences, it is possible to say that the study will make a contribution to the empirical literature on the subject.

The second part of the study covers the literature review on the subject. The next part (third section) introduces information on the dataset and empirical method. The fourth and fifth sections present econometric tests and findings, and general evaluation and conclusion remarks, respectively.

## 2. Literature Review

Despite the economic, social, and environmental importance of the energy factor, neoclassical economics has led to a long period the downplay of the role of energy on economic growth. Because, according to these models, energy and natural resources are intermediate inputs used in production and do not have a direct impact on economic growth. In the long run, economic growth only affects labor, capital, and land (Stern, 2004; Ben-Salha, Hkiri, and Aloui, 2018). However, with the effects of the economic, social, and environmental events and facts mentioned earlier since the 1980s, energy-growth relationships have attracted the attention of both economists and policy-makers. In this framework, while the world bank and OECD consider renewable energy and sustainability concepts within green growth criteria (World Bank, 2012; OECD, 2017), on the other hand, the energy-growth relationship has become the focus of academic research.

Together with the pioneering work of Kraft and Kraft (1978), it is possible to classify in three groups the previous studies investigating the energy-growth nexus. In general, in the first group of studies are analyzing the relationship between *energy consumption and growth*, four different hypotheses are tested. These are neutrality, conservation, growth, and feedback hypotheses. In these hypotheses are stated that there is no relation between growth and energy consumption, the direction of causality is from economic growth to energy or vice versa, and there is a bidirectional causality relation, respectively.[3]

The second group of studies focuses on the relations between *renewable energy consumption and growth.* Different results have found in each of the studies conducted several methods (time series or panel data) for different country/country groups. For example, in Fang (2011), Doğan (2015) and Koç (2020)[4] studies, result supporting the growth hypothesis is obtained,

[3] For detailed information and case studies, see Payne (2010), Öztürk (2010) and Omri (2014).

[4] The study by Koç (2020a), unlike others, examines the effects of sectoral energy consumption on growth by using a panel data method for 132 countries. For another study of the author on the subject, see Koç, (2020b).

while Menegaki (2011), Yıldırım et al. (2012), Bulut and Muratoğlu (2018) found results that support the neutrality hypothesis. In contrast, Tuğcu et al. (2012), Bloch et al. (2015), Shahbaz et al. (2015), Doğan (2016), Kahia et al. (2017) and Durğun and Durğun (2018) supported the feedback hypothesis, while Furuoka (2017) and Alper (2018) showed findings supporting the conservation hypothesis.

Finally, the third group studies investigate the effects of *renewable energy production on growth*. It is possible to summarize the previous studies we can identify in the literature review as follows:

The study by Bayraktutan, Yılgör, and Uçak (2011) investigates the relationship between renewable electricity generation and growth in OECD countries for the 1980-2007 period. According to the findings of the analysis, there is a positive long-run relation and unidirectional causality between the variables. Shortly, the study has produced results that support the growth hypothesis.

Examining the impact of renewable energy production on growth in 20 OECD countries, Ohler and Fetter (2014) apply the panel error correction model and panel causality tests. According to the study using data from 1990-2018, there is bidirectional causality between renewable energy production and growth, and a positive long-run correlation between renewables components and GDP. The study supports the feedback hypothesis.

Twari, Apergis, and Olayeni (2015) explore asymmetric effects between growth and renewable and nonrenewable energy generation in 12 sub-Saharan African countries in the 1971-2011 period. The study has revealed different empirical results for the countries that divided into two subsets. The findings confirm the growth hypothesis for the first subset countries, and in these countries, conservative policies negatively affect growth. On the other hand, the results of the second subgroup countries confirm the conservation hypothesis, and the conservation policies improve the economic growth in these countries.

The study by Bento and Moutinho (2016) investigating the causality relation among renewable energy and growth for Italy between 1961 and 2011 has employed the Autoregressive Distributed Lag (ARDL) model. According to the study, increases in growth rate encourage renewable energy production. In other words, the study provides a result that supports the conservation hypothesis.

Another research on the subject is Bekhet and Harun (2017) for Malaysia. In the study using ARDL and vector error correction model (VECM), like Bentho and Moutinho (2016), the result supporting the conservation hypothesis has found.

Atems and Hotalling (2018), investigates the effects of renewable energy (electricity) generation on economic growth by using the data set of 174 countries between 1980 and 2012. In the study employing the system GMM model, it has found a significant and positive correlation between the variables. Besides, the study exhibited a finding that confirms the feedback hypothesis among the variables.

Khobai (2018) analyses the causality relations between renewables production and growth using quarterly data of the 1997-2012 period and VECM for South Africa. According to the Granger causality test results in the study, there is a unidirectional relation running from renewable energy to growth. So, the findings confirm the growth hypothesis.

The last research we can find in the literature review is the study for the Nigerian economy by Oyeleke and Akinlo (2019). The study, in which the data of the 1980-2017 period has analyzed with the error correction model, finds that renewable energy production affects economic growth positively in the short-run and negatively in the long-run. However, the causality relationship between the variables has not investigated in the study.

## 3. Data and Methodology

### 3.1. Data

The variables used in the study have determined according to the following economic model expressed by Stern (2004):

$$GDP_t = f(Cap_t, Emp_t, Renewpro_t) \quad (1)$$

In equation (1) $GDP_t$, $Cap_t$, $Emp_t$, and $Renewpro_t$ represent at time $t$ gross domestic production, capital stock, employment level, and renewable energy production in Turkey, respectively. The log-linear reduced form equation can be specified as follows:

$$loggdp_t = \alpha_0 + \alpha_1 logcap_t + \alpha_2 logemp_t + \alpha_3 logrenewpro_t + \varepsilon_t \quad (2)$$

where $\varepsilon_t$ represents error term.

In equations (1) and (2), capital stock, employment, and renewable energy production are independent variables, and real GDP is the dependent variable. The data set, which belongs to Turkey, covers the periods of 1990-2017. We took wind energy production data from the BP Statistical Review of World Energy data set (BP, 2020), GDP and capital stock data from the Penn World Table version 9.1 and employment data from the Turkish Statistical Institute (www.turkstat.gov.tr). While Table 2 shows information about the variables, Table 3 gives information about the descriptive statistics for these variables.

**Table 2: Definition of the Variables**

| Variables | Definitions | Source |
|---|---|---|
| *loggdp* | Output-side real gross domestic product (at chained PPPs, in millions 2011 US Dollar) | Penn World Table version 9.1 |
| *logcap* | Capital stock (at 2011constant national prices, in millions US Dollar) | |
| *logemp* | Employment (15+ population, in millions) | TURKSTAT |
| *logrenewpro* | Renewable energy generation (terawatt-hours) | BP (2020) |

**Table 3: Descriptive Statistics of the Variables**

| Variables | *loggdp* | *logcap* | *logemp* | *logrenewpro* |
|---|---|---|---|---|
| Mean | 13.76328 | 14.72024 | 16.91667 | -0.106256 |
| Median | 13.55705 | 14.37444 | 16.87142 | -0.495271 |
| Maximum | 14.60457 | 15.93671 | 17.27003 | 1.463065 |
| Minimum | 13.20133 | 13.96215 | 16.73323 | -1.096367 |
| Std. Dev. | 0.443686 | 0.701215 | 0.147597 | 0.805995 |
| Skewness | 0.539820 | 0.527786 | 1.156184 | 0.725244 |
| Kurtosis | 1.937187 | 1.751170 | 3.339838 | 2.018119 |
| Jarque-Bera | 2.677725 | 3.119441 | 6.372959 | 3.579342 |
| Probability | 0.262144 | 0.210195 | 0.041317 | 0.167015 |
| Observations | 28 | 28 | 28 | 28 |

### 3.2. Econometric Methodology

In the study, we have employed the ARDL method, which developed Pesaran and Shin (1999) and Pesaran et al. (2001), in researching the role of renewable energy production in sustainable economic growth. The main reason for choosing this method is that it has some advantages (Pesaran and Pesaran, 1997: 302-3003, Narayan, 2005). The first of these is that it is possible to estimate the short-run and long-run effects of the explanatory variables simultaneously in this method. The second advantage is that this approach allows long-run relations between variables to be determined independently of the stationarity degree of the variables. Thirdly, this model can be applied to the studies consisted of few observations, and be estimated robust and consistent long-term coefficients. As Narayan and Narayan (2004) stated, what is critical in this model is the length of the period considered rather than the number of observations. And finally, each variable in this method can take a different lag length.

## 4. Econometric Tests and Results

### 4.1. Unit Root Tests

Although ARDL models make it possible to analyze variables with different degrees of stationary, the variables should not be *I(2)* (Narayan and Narayan, 2004). Thus, the stationary of the variables was analyzed employing the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests. Test results have shown in Table 4. As can be seen, all of the variables have a unit root at the level, and the first differences are stationary. The other words, all variables are *I(1).* The results show that the role of renewable energy production on growth can analyze by the ARDL model.

**Table 4: Unit Root Tests Results**

| | ADF Test | | PP Test | |
|---|---|---|---|---|
| | *Test Statistics* | *Critical Value (5%)* | *Test Statistics* | *Critical Value*** *(5%)* |
| *loggdp* | **1.381882** | -2.976263 | **1.631710** | -2.976263 |
| *logcap* | **-0,122601** | -2.981038 | **0.684306** | -2.976263 |
| *logemp* | **1.154425** | -2.976263 | **1.154425** | -2.976263 |
| *logrenewpro* | **0.653428** | -2.981038 | **0.616672** | -2.976263 |
| *Δloggdp* | -4.556924 | -2.981038 | -4.558607 | -2.981038 |
| *Δlogcap* | -3.107848 | -2.981038 | -3.142082 | -2.981038 |
| *Δlogemp* | -4.198744 | -2.981038 | -4.195362 | -2.981038 |
| *Δlogrenewpro* | -3.709723 | -2.981038 | -3.777317 | -2.981038 |

*Notes:* All test statistics show the critical values of MacKinnon (1996) calculated in the 5% confidence interval of the respective tests. The tests were conducted under the assumptions of an intercept, intercept and deterministic trend. If the test included only the intercept is stationary, the test including the intercept and trend has been applied. Thus, all deterministic and stochastic properties are taken into account in determining the stationary of the series.

### 4.2. ARDL Results

The two-stage process is applied when analyzing the relationships between variables in the ARDL model. In the first stage, whether there is a long-term relationship between the variables is investigated by the bound test. In other words, the existence of the cointegration relationship between the variables is tested. The short-run and long-run parameters of the model are estimated in the second stage if the variables are cointegrated.

Undoubtedly, before applying these steps, an unrestricted error correction model (UECM) is created. The UECM model used in this study can demonstrate as follows:

$$\Delta loggdp_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta loggdp_{t-i} + \sum_{i=0}^{p} \alpha_{2i} \Delta logcap_{t-i} + \sum_{i=0}^{p} \alpha_{3i} \Delta logemp_{t-i} + \sum_{i=0}^{p} \alpha_{4i} \Delta logrenewpro_{t-i} + \alpha_5 loggdp_{t-1} + \alpha_6 logcap_{t-1} + \alpha_7 logemp_{t-1} + \alpha_8 logrenewpro_{t-1} + u_t \quad (3)$$

where *p* is the number of lags.

In the ARDL model, the optimal lag length is determined by the smallest AIC or SIC critical value, in which the likelihood of autocorrelation is the lowest. Table 5 presents the results of the lag length test. The results of the analysis, in which the maximum lag length was four, showed that the optimal lag length is two since the likelihood of autocorrelation is the lowest (0.9434).

**Table 5: Optimal Lag Length Selection**

| *p* | *AIC Criteria* | *LM Test* |
|---|---|---|
| 1 | -3.282596 | 0.2141 |
| 2 | -3.520755 | 0.9434 |
| 3 | -3.512328 | 0.8023 |
| 4 | -3.877180 | 0.3592 |

In the ARDL approach, the existence of long-term relationships between variables is determined by equating the lagged coefficients of the dependent and independent variables in equation 3 to zero ($\alpha_5 = \alpha_6 = \alpha_7 = \alpha_8 = 0$) and then applying the *F* bound test. As a result of the bound test, if the calculated *F* statistic value is greater than the upper critical value *(I(1))*, this indicates that there is a long-term relationship between the variables. As can be seen from Table 6, the F statistic value is greater than the upper critical value in all confidence intervals. Therefore, there is a long-run relationship between renewable energy production and other control variables and growth.

**Table 6: Bound Test Result**

| *F Statistic* | *k* | *Critical Values* | | | | | |
|---|---|---|---|---|---|---|---|
| | | *1%* | | *5%* | | *10%* | |
| | | I(0) | I(1) | I(0) | I(1) | I(0) | I(1) |
| 7.474478 | 3 | 5.17 | 6.36 | 4.01 | 5.07 | 3.47 | 4.45 |

*Notes:* k is the number of independent variables. *I(0)* and *I(1)* are respectively lower and upper critical values in Pesaran et al. (2001:300)

After determining the long-run relations between the variables, the ARDL (2, 0, 1, 0) model summarized in Table 7 has estimated. According to the diagnostic test results, there were no problems in the model. Breusch-Godrfey LM test showed that the model did not contain autocorrelation, and the ARCH-LM test did not reveal the problem of heteroscedasticity. The Jarque-Bera statistic value shows that the residuals have the normal distribution. Ramsey RESET test shows that the functional form of the model established correctly. Finally, CUSUM and CUSUM-of-Square tests were performed to test the stability of the predicted model, that is, whether there was a structural change. According to the test results shown in Figure 1, there are no structural breaks in the estimation period.

**Table 7: Estimation Results of ARDL (2, 0, 1, 0)**

| **Dependent Variable: loggdp** | | | | |
|---|---|---|---|---|
| **Variable** | **Coefficient** | **Std. Error** | **t-Statistic** | **Prob.** |
| loggdp (-1) | 0.123145 | 0.195648 | 0.629422 | 0.5370 |
| loggdp (-2) | -0.564943 | 0.180352 | -3.132450 | ***0.0058*** |
| logcap | 0.409166 | 0.079666 | 5.136042 | ***0.0001*** |
| logemp | 0.068562 | 0.266640 | 0.257135 | 0.8000 |
| logemp (-1) | 0.394002 | 0.248316 | 1.586697 | 0.1300 |
| logrenewpro | 0.161746 | 0.051337 | 3.150661 | ***0.0055*** |
| C | 5.716306 | 2.528643 | 2.260622 | ***0.0364*** |
| @TREND | 0.018839 | 0.005160 | 3.651079 | ***0.0018*** |

| | | | |
|---|---|---|---|
| R-squared | 0.994797 | Breusch-Godfrey LM test: | 0.690244(0.6794) |
| Adjusted R-squared | 0.992773 | Heteroskedasticity ARCH-LM test: | 0.281642(0.7573) |
| Durbin-Watson stat | 1.942612 | Normality test: | |
| F-statistic | 491.6021 | *Skewness* | -0.126084 |
| Prob (F-statistic) | 0.000000 | *Kurtosis:* | 2.791478 |
| | | *Jarque-Bera* | 0.115993(0.9436) |
| | | Ramsey RESET Test: | 2.475559(0.1157) |

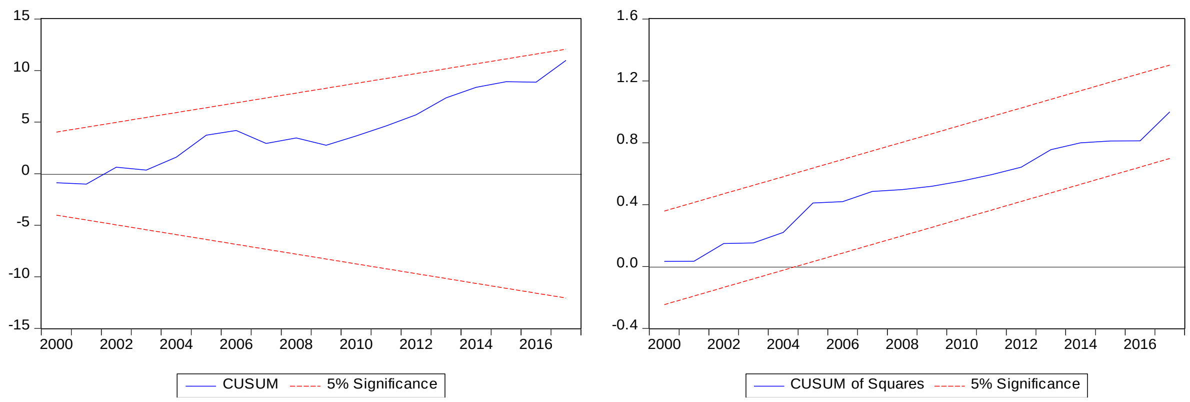


**Figure 1: CUSUM and CUSUM of Square Tests**

In the next step, the long-run coefficients of variables are estimated. Table 8 summarizes the long-run estimation results for ARDL (2,0,1,0) model. Accordingly, the coefficients of the independent variables are statistically significant and there is a positive relationship between capital stock, employment, renewable energy generation, and growth. In other words, economic growth increases as capital stock, employment, and renewable energy production increase. On the other hand, the impact of renewable energy production on economic growth is smaller than the other two factors. This situation is not an expected case and not surprising.

However, given that the amount of renewable energy production is relatively low, it is not possible to deny the importance of this effect.

Finally, according to the results, the error correction coefficient is negative (-1.441798) and statistically significant. In other words, the short-run disturbances are eliminated in the long-run, and the system is converging to equilibrium. In the model, 11% of the short-run imbalances are eliminated every year.

**Table 8: Long-run Estimation Results of ARDL (2, 0, 1, 0) Model**

| Variable | Coefficient | Std. Error | t-Statistic | Probability |
|---|---|---|---|---|
| *logcap* | 0.283789 | 0.042859 | -6.621440 | 0.0000 |
| *logemp* | 0.320824 | 0.097731 | 3.282734 | 0.0041 |
| *logrenewpro* | 0.112183 | 0.029990 | 3.740746 | 0.0015 |
| CointEq(-1) | -1.441798 | 0.208534 | -6.913968 | 0.0000 |
| EC = loggdp – (0.2838*logcap + 0.3208*logemp + 0.1122*logrenewpro) | | | | |

## 5. Conclusion

The paper empirically analyzes the role of renewable energy production on economic growth. The study, which adopts the ARDL model, uses the data of Turkey between 1990 and 2017. Besides, capital stock and employment have employed as control variables to distinguish the role of renewable energy generation. Our main result is that renewable energy production positively affects growth, like capital stock and employment. The most important aspect of this result is that it has partially falsified the mainstream theory, which considers energy and natural resources as intermediate inputs. Another critical point is that although the amount of renewable energy production is low, it has an undeniable effect on economic growth. Considering its economic, social and environmental impacts, the effects of increases in renewable energy production on growth may become more evident.

Although the purpose of this study is not to peruse causality relationships between variables, it is possible to say that the findings obtained in this paper are in line with those in studies (Bayraktutan, Yılgör and Uçak (2011), Khobai (2018)) supporting the growth hypothesis. For example, Bayraktutan, Yılgör, and Uçak (2011) state that the increase in renewable energy production (electricity) contributes positively to growth. Unlike others, Ohler and Fetter (2014), which also takes into account the effects of wind energy, suggests that there is a positive long-run relation among renewable energy sources and GDP. Oyeleke and Akinlo (2019) found a negative relationship between renewable energy production and growth. In this respect, it differs from both our and other studies that support the growth hypothesis.

Consequently, different results are likely to occur depending on the social, economic, and environmental conditions of each country. However, although the amount of low production, renewable energy production reveals a positive impact on economic growth in Turkey.

Therefore, it is apparent that more investment should be made in the field of renewable energy, considering its social and environmental impacts.

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