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# ECONOMIC IMPACTS OF RENEWABLE ENERGY AND SUPPLY CHAIN IN TURKEY

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**Abstract:**
*The fact that the reserves of traditional energy sources will run out over the years and the problem of external dependency have led to the development of a renewable energy alternative. In addition to supply and cost problems, traditional energy sources can cause irreversible damage to nature. The need for energy is increasing day by day and is directly related to the existence of living communities, human beings and civilizations in every region of life and all over the world. The need for energy and energy-related activities is growing in order to realize economic growth, social improvement and to improve social welfare and health. This study consists of 30 annual observations between 1991 and 2020. While GDP is the Gross Domestic Product for the Turkish economy in constant dollars for 2015, RNE represents the percentage of renewable energy consumption in total energy consumption. In the study, whether the series are stationary or not was tested with Augmented Dickey–Fuller (ADF) unit root test and Phillips–Perron (PP) unit root tests. It has seen that ADF and PP unit root test findings were obtained for the variables. In this case, it was determined that both variables in the research models were first order stationary variables. There is a statistical cointegration relationship between the variables at the 1% significance level. When the Toda-Yamamoto causality test was applied, it was determined that there was no causality from the renewable energy consumption rate to the Gross Domestic Product; A statistically significant causality was detected from Gross Domestic Product to renewable energy consumption rate.*

**Keywords:**
Renewable energy consumption, Gross Domestic Product, ARDL limit test, Toda-Yamamoto

## 1. Introduction

One of the main drivers of economic and social progress in the world is energy. In the renewable energy section of many countries, economic practices and population growth lead to increased energy use. (Sadorsky, 2021). The manufacturing industry consumes approximately half of the global energy supply. Economic activity and social variables increase energy use.

Energy is currently a serious concept that has a significant impact on the public in terms of social and economic recovery, food production, ending poverty, health, peace and security. As a result of studies on fossil energy; The rate of energy consumed on earth is 300 thousand times the rate of fossil energy formation (Kaya, Şenel , & Koç, 2018). Traditional energy sources may cause external dependency and possible reserve problems, and their use causes irreversible damage to nature. Fossil fuels, which have been transformed from natural organisms from past to present, are exhaustible resources that can cause irreversible problems to nature. The idea that the reserves of non-renewable energy resources will not be sufficient over the years and the problem of foreign dependency have led to renewable energy resources.

The need for electrical energy is increasing in connection with the development of technology in the world. Population growth and technology bring demand for electricity. As energy needs increase, countries with sufficient energy resources are in a strong position. States with developed industries are carefully researching different resources to benefit from non-conventional energy.

When considered from the perspective of the supply chain, it is an energy source whose energy is inexhaustible and which is not difficult to convert into energy that does not have transportation problems. The wind source is present in the air and does not harm nature. In order to produce wind energy, it is necessary to transform it into a different energy.

In the study, renewable energy and its impact on economic growth in Turkey are detailed, and at the end of the study, attention is drawn to the importance of renewable energy within the scope of its economic effects; An analysis was made to measure the use of renewable energy in Turkey and the contribution of renewable energy to the economy in Turkey.

## 2.Renewable Energy in Turkey

Renewable energy networks cause minimal environmental damage compared to traditional energy networks; It does not create physical waste, especially in terms of greenhouse gases, it does not consume natural resources, and the things it benefits from are abundantly available in nature. Global warming, energy use and financial consequences, feedback links, mobilization and indirect effects of production markets are adjacent to each other (Kucukvar, Cansev, Egilmez, Onat, & Samadi, 2016).

### 2.1.The Effect of Renewable Energy on Economic Growth

Energy, which is the most important tool that ensures the survival of the economy, is one of the important means of social and economic recovery and one of the essential strategic results. Energy is a strategic origin that affects the outcome of conflicts, enhances or suppresses financial recovery, harms or does not harm nature. One of the most important problems of the modern world is the climate crisis and the damage it causes to nature. Human activities, most importantly energy use, are among the main factors contributing to the climate crisis in recent times. In order to counter the degradations that may occur in nature in the future, innovation must be made in the energy production practices currently implemented, among other measures (Inglesi-Lotz, 2016). Traditional energy resources are generally used for energy purposes in developing nations, but since these resources are conventional resources, their reserves are not permanent. However, the production of these resources can destroy nature compared to renewable energy sources that can minimize CO2 emissions and damage to nature. Minimizing emissions, increasing energy performance or managing energy demand, etc. measures have an impact on financial development (Ozcan & Ozturk, 2019).

Population growth and financial development at global and local levels have a significant and positive impact on CO2 emission levels. Energy consumption is the cause or facilitator of financial development (Ram, Aghahosseini, & Breyer, 2020). As financial development occurs, emissions increase, and financial development often explains increased energy use and high CO2 emissions; Therefore, encouraging financial transfer to non-conventional energy is an effective factor in reducing environmental barriers (Dong, et al, 2018). A full understanding of the relationship between CO2 emissions, financial development, population growth and renewable energy is of particular benefit to politicians and government officials. The transfer of renewable electricity towards excess rates has reactions such as surplus production potentials, investment requirements and reductions in greenhouse gas emissions.

While the global population has increased almost 2.5 times since 1950, energy demand has also increased 7 times (Sengül, Eren, Shiraz, Gezder, & Sengül, 2015). Currently, the energy needs of many countries are met from non-renewable, traditional energy sources. Although traditional energy resources are not infinite in terms of reserves, their production causes irreversible damage to nature and causes emission and climate crises. While the elimination of financial restrictions reduces the CO2 emission level on an estimated individual basis, the increase in population increases the CO2 emission level on an individual basis across areas in the long run (Alper & Oguz, 2016). While non-traditional, inexhaustible energy sources play a role in reducing CO2 emissions and minimizing the damage to nature, they eliminate foreign dependency and provide employment since they are natural resources.

Realization of sustainability in utilizing energy; Possible outcomes such as ensuring profitability in energy with inexhaustible energy sources, rapid access to electricity, increase in investments due to interest in clean nature and applications will occur (Bhattacharya, Paramati, Ozturk, & Bhattacharya, 2016). Energy efficiency is an affordable way to minimize emissions, increase energy security and competitiveness potential, and reduce energy prices (Alper & Oguz, 2016). Energy efficiency can be achieved by increasing the production and use of non-traditional, inexhaustible energy.

With the increasing emphasis on climate change problems, there is a great need to determine the method of reducing greenhouse gases while creating sustainable financial development. The European financial structure is, however, subject to energy origins and vulnerable to rising energy costs and raw commodity exposures; Therefore, policy makers are encouraged to make the right decisions for an extra green and efficient economy in terms of origin (Kucukvar, Cansev, Egilmez, Onat, & Samadi, 2016). The European manufacturing industry is therefore stated as one of the important policy scopes that require rapid attention. Compared to 1990 levels, the EU approved the Energy and Climate Framework, considering the year 2030 to reduce greenhouse gas emissions by 2/5 (Markandya, Arto, Román, & González-Eguino, 2016).

Applications should be aimed at reducing energy frequency, achieving energy demand security, minimizing the dangers caused by addiction, and increasing the activity to prevent climate change (Sengül, Eren, Shiraz, Gezder, & Sengül, 2015). Non-traditional energy technologies are used more than once to produce electricity. They are energy resources widely used by developed and developing countries.

Considering renewable energy as a factor in itself may overshadow the different qualities of individual renewable energy sources, which may help to take appropriate precautions. Those who carry out national politics can implement quality recovery tactics by reconciling the relationship between energy, nature and finance, taking into account the results of the examination. Most states in the development process, similar to advanced states, want to reduce their share of dependence on traditional resources by increasing their non-traditional energy investments (Ozcan & Ozturk, 2019).

Job creation trends vary significantly across different energy manufacturing technologies (Ram, Aghahosseini, & Breyer, 2020).The increased productivity associated with financial development reduces some jobs; This is a reaction that affects not only traditional energy but also all other technologies. This increased industrial productivity and the continued scrutiny of renewable energy and conservation technologies may provide additional jobs in the future (Ram, Aghahosseini, & Breyer, 2020).

**2.2.Literature Review**

National and international studies are listed in the table below.

**Table 1: Empirical Studies Examining the Relationship between Renewable Energy Consumption and Gross Domestic Product**

| AUTHOR, YEAR | WORKING PERIOD | BASIS COUNTRY/ COUNTRIES | VARIABLES | METHOD | CONCLUSION |
|---|---|---|---|---|---|
| (Hasnisah, Azlina, & Taib, 2019) | 1980-2014 | 13 developing countries in Asia | GDP, RE, $CO_2$ ,FOSS | Panel Cointegration, OLS | The existence of the inverted U-shaped EKC hypothesis is confirmed in 13 Asian countries. |
| (Zhao, Zhang, Ali, & Chen, 2023) | 1975-2020 | Developing Asian countries | REC, NREC, GDP, CC, URB, TIN | STIRPAT model, AMG | The existence of the inverted U-shaped EKC hypothesis is confirmed for emerging Asian economies. |
| (Wang, Ali, Chen, & Xu, 2023) | 1970-2020 | Seven Northeast Asian Countries | REC, NREC, GDP, $CO_2$ | Panel causality, FMOLS, DOLS | Within the scope of the selected Seven Northeast Asian Countries, a bidirectional causality relationship has been determined between renewable energy consumption and economic growth. |

| | | | | | |
|---|---|---|---|---|---|
| (Eren, Taspinar, & Gokmenoglu, 2019) | 1971-2015 | India | REN, GDP, FD | Granger causality, VECM | It has been determined that economic growth with renewable energy is focused on financial development in the long term and a bidirectional causality relationship between renewable energy and economic growth. |
| (Mahmood, Wang, & Hassan, 2019) | 1980-2014 | Pakistan | GDP,REC,NREC;HC,TR | VECM, Granger causality test | In the study, it was determined that the EKC hypothesis is valid in Pakistan. |
| (Ocal & Aslan, 2013) | 1990-2010 | Turkey | GDP, RE, K,L | ARDL, Toda-Yamamoto | In a Turkey-based study, a unidirectional causality relationship was found from economic growth to renewable energy. |
| (Lin & Moubarak, 2014) | 1977-2011 | China | RE, GDP, CD, LB | ARDL, Johansen Cointegration | In a China-based study, a bidirectional causality relationship was found between renewable energy and economic growth. |
| (Shahbaz, Loganathan, Zeshan, & Zaman, 2015) | 1972-2011 | Pakistan | GDP, RNE, K,L | VECM, Granger Causality, ARDL | A Pakistan-based study found a bidirectional causality relationship between renewable energy and economic growth. |
| (Durğun & Durğun, 2018) | 1980-2015 | Turkey | GDP, RNW | ARDL, Toda-Yamamoto | In a Turkey-based study, a bidirectional causality relationship was found between renewable energy and economic growth. |

## 3.Methodology and Method

### 3.1.Data Set

The data is in the form of 30 annual data between 1991 and 2020, with World Bank as the source; Sourced from World Development Indicators (WDI), the primary compilation of development indicators. In addition, in this part of the research, the research model, the variables used in the research and the econometric methods used during data analysis are stated.

### 3.2. Research Model

Within the scope of the research, it is aimed to estimate the research model in equation 1 to determine the effect of renewable energy consumption on Gross Domestic Product.

$$\ln GDP_t = \alpha + \beta \ln RNE_t + \varepsilon_t \qquad (1)$$

The t subscript in the equation refers to the time dimension and consists of 30 annual observations between 1991 and 2020. While α represents the constant term, ε represents the error terms of the equation assumed to be in the pure random walk process. ($\varepsilon \sim N(\mu,\sigma)$). $\beta$ is the coefficient that estimates the impact of renewable energy consumption on Gross Domestic Product. The ln prefixes in front of the variables indicate that the variables are included in the model logarithmically. While GDP is the Gross Domestic Product in constant Dollars for the Turkish economy in 2015, RNE represents the percentage of renewable energy consumption in total energy consumption.

**3.3. Data Analysis**

In the study, it was tested whether the series were stationary or not by Augmented Dickey–Fuller (ADF) unit root test and Phillips–Perron (PP) unit root tests (D.Dickey & W.A.Fuller, 1979, s. 427-431). The selection of the optimal delay length required for the ADF test is according to the Akaike Information Criterion, and the selection of the optimal bandwidth required for the PP unit root test is based on the Newey -Taken as a criterion from the West method (Sevütekin & Çınar, 2017). On the other hand, in order to decide the stationarity of variables with structural breaks, ADF unit root tests with structural breaks were also applied and stationarity decisions were made by comparing the findings.

For variables that are not stationary at level but become stationary at the first cycle difference, it is a common practice in traditional econometrics to use the variables by taking their differences. However, it was explained by Granger and Newbold that it is not appropriate to use non-stationary variables in this way because it eliminates information about the long-term relationship (Granger & P.Newbold, 1977).

The aim of the research is to examine the relationships between variables that are found to be non-stationary using the ARDL cointegration approach.

The ARDL bounds testing approach consists of two stages. The first stage tests the existence of a long-term relationship between variables. In the second stage, the short and long term coefficients of the series determined to be cointegrated in the first stage are calculated. For understandability, the following equation is estimated to test the long-run relationship in the bounds testing approach for a two-variable research model (Pesaran & Y.Shin, 2001).

$$\Delta Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 X_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-1} + \sum_{i=0}^{q} \lambda_i \Delta X_{t-i} + \mu_t \tag{2}$$

In the equation;

p = optimal number of lags in the dependent variable

q = optimal number of lags in the independent variable

Coefficients $\beta_0$ , $\beta_1$, $\beta_2$ , $\delta_i$ and $\lambda$

$\Delta$ = It represents the difference of the variable.

The null hypothesis for the cointegration relationship between the variables is as follows;

$$H_0: \beta_1 = \beta_2 = 0$$

If the calculated test statistic is less than the determined lower critical limit, the null hypothesis stating that there is no cointegration relationship cannot be rejected. If the test statistic is greater than the determined upper critical limit, the null hypothesis stating that there is no cointegration relationship is rejected and it is decided that there is cointegration. If the test statistic is between the lower and upper limit values, a decision cannot be made regarding cointegration.

After it is determined that there is cointegration between the series, the ARDL(p,q) model is estimated. The ARDL(p,q) model is shown in the equation below.

$$Y_t = \beta_0 + \sum_{i=1}^{p} \delta_i Y_{t-i} + \sum_{i=1}^{p} \lambda_i X_{t-i} + \mu_t \tag{3}$$

In the ARDL(p,q) model, long-term coefficients for the independent variable are estimated as follows.

$$\theta_i = \frac{\lambda_0 + \lambda_p + \cdots . \lambda_p}{1 - \delta_1 + \delta_2 + \cdots \delta_q} \quad (4)$$

After estimating long-term coefficients, short-term coefficients are obtained by establishing an error correction model.

$$\Delta Y_t = \beta_0 + \beta_1 EC_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + \sum_{i=1}^{q} \lambda_i \Delta X_{t-i} + \mu_t \quad (5)$$

EC in the equation refers to the error correction term. In order to test the existence of a causal relationship from the independent variables to the dependent variable, the error correction term must be significant and within the range of 0 and -1.

Toda-Yamamoto causality analysis is based on the extended VAR model. The extended VAR model includes two different lag lengths. The first is the optimal lag length (k) of the standard VAR model, while the second is the highest degree of integration (dmax) of the variables included in the VAR model. Examining mutual causality for two variables is done as follows;

$$Y_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} Y_{t-1} + \sum_{i=k+1}^{k+d_{max}} \beta_{2i} Y_{t-i} + \sum_{i=1}^{k} \delta_{1i} X_{t-i} + \sum_{i=k+1}^{k+d_{max}} \delta_{2i} X_{t-i} + \mu_{1i} \quad (6)$$

$$X_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} X_{t-1} + \sum_{i=k+1}^{k+d_{max}} \alpha_{2i} X_{t-i} + \sum_{i=1}^{k} \theta_{1i} Y_{t-i} + \sum_{i=k+1}^{k+d_{max}} \theta_{2i} Y_{t-i} + \mu_{2i} \quad (7)$$

After the equations are estimated with the VAR system, the significance of the coefficients of the explanatory variables is tested with the Wald test. If the coefficients are different from zero together, it is interpreted as the explanatory variable in question having a causal effect on the explained variable (Toda & Yamamoto, 1995).

### 3.4. Results

In this part of the research, the findings obtained as a result of data analysis are discussed. Descriptive statistics of the variables included in the research model are shown in Table 2.

**Table 2: Variable Descriptive Statistics**

| **Statistics** | **lnGDP** | **lnRNE** |
|---|---|---|
| Average | 27.010 | 2.778 |
| Median | 27.021 | 2.693 |
| Maximum | 27.647 | 3.180 |
| Minimum | 26.396 | 2.434 |
| Standard deviation | 0.401 | 0.249 |
| Coefficient of Skewness | 0.168 | 0.350 |
| Kurtosis Coefficient | 1.727 | 1.698 |

| | | |
|---|---|---|
| Jarque-Bera Normality Test | $\chi^2(02)=2.168$ | $\chi^2(02)=2.733$ |
| | [0.338] | [0.255] |
| Number of Observations | 30 | 30 |

The lnGDP variable shows a normal distribution around a mean of 27,010, between minimum 26,396 and maximum 27,647 values. ($\chi^2(02)=2.168$). The lnRNE variable shows a normal distribution around a mean of 2.778, between minimum 2.434 and maximum 3.180 values.($\chi^2(02)=2.733$)
ADF and PP unit root test findings are as in Table 3.

**Table 3: ADF and PP Unit Root Test Findings**

| **Variable** | **ADF** | | **PP** | |
|---|---|---|---|---|
| | **Constant** | **Constant And Trend** | **Constant** | **Constant And Trend** |
| **LnGDP** | $-0.132^{(0)}$ | $-2.391^{(0)}$ | $0.068^{\{6\}}$ | $-2.458^{\{3\}}$ |
| | [0.937] | [0.376] | [0.958] | [0.345] |
| **Δ lnGDP** | $-5.252^{(0)***}$ | $-5.159^{(0)***}$ | $-5.723^{\{6\}***}$ | $-5.674^{\{6\}***}$ |
| | [0.000] | [0.001] | [0.000] | [0.000] |
| **LnRNE** | $-1.765^{(2)}$ | $-1.887^{(1)}$ | $-1.549^{\{0\}}$ | $-1.613^{\{2\}}$ |
| | [0.389] | [0.635] | [0.495] | [0.763] |
| **Δ lnRNE** | $-5.765^{(1)***}$ | $-6.286^{(1)***}$ | $-6.391^{\{0\}***}$ | $-7.634^{\{4\}***}$ |
| | [0.000] | [0.000] | [0.000] | [0.000] |

*** (1%), ** (5%), * (10%) Represent Significance at the Significance Level.

In Table 3, ADF and PP unit root tests performed for the lnGDP variable show that the variable is not stationary at level (p>0.10), but is a variable that becomes stationary at the first cyclical difference, in line with the test statistics calculated for constant and trend models. (p<0.01). Similarly, the ADF and PP unit root tests performed for the lnRNE variable show that the variable is not stationary at level (p>0.10), but is a variable that becomes stationary at the first cyclical difference, in line with the test statistics calculated for constant and trend models. (p<0.01).
The findings of the ADF unit root test with structural breaks applied to the variables are as shown in Table 4.

**Table 4: DF Unit Root Test Findings with Structural Breaks**

| **Variable** | **ADF Specifications** | | | |
|---|---|---|---|---|
| | **Constant** | **Fracture Specifications** | | |
| | | **Constant And Trend** | | |
| | | **Constant** | **Trend** | **Constant And Trend** |
| **lnGDP** | $-1.753^{(0)}$ | $-5.025^{(2)}$** | $-4.837^{(3)}$** | $-5.181^{(2)}$** |
| | [0.999] | [0.031] | [0.020] | [0.049] |
| **Δ lnGDP** | $-5.897^{(0)}$*** | $-5.025^{(2)}$** | $-5.379^{(0)}$*** | $-6.176^{(0)}$*** |
| | [0.000] | [0.031] | [0.000] | [0.000] |
| **lnRNE** | $-2.991^{(2)}$ | $-3.481^{(0)}$ | $-4.911^{(1)}$** | $-6.271^{(1)}$*** |
| | [0.691] | [0.704] | [0.017] | [0.000] |
| **Δ lnRNE** | $-7.436^{(1)}$*** | $-7.239^{(1)}$*** | $-6.964^{(1)}$*** | $-7.738^{(1)}$*** |
| | [0.000] | [0.000] | [0.000] | [0.000] |

*** (1%), ** (5%), * (10%) Represent Significance at the Significance Level.

When the table is examined, it is seen that findings compatible with the ADF and PP unit root test findings were obtained for both lnGDP and lnRNE variables. In this case, it can be said that both variables in the research models are first-order stationary (I(1)) variables.

ARDL model prediction findings are included in Table 5. The table first includes the findings of the autoregressive distributed lag model, then the F bound test statistics, long-term coefficients, error correction model and short-term coefficients. The last part includes findings regarding diagnostic tests. It is known that for the ARDL model, it is not possible to interpret the lag-distributed autoregressive model coefficients as long- or short-term coefficients, and these coefficients are used in the long-term coefficient calculation. For this reason, interpretations are made within the framework of long-term and short-term coefficients and cointegration tests.

**Table 5: Model Estimation Findings**

| **Autoregressive Model: Dependent Variable lnGDP** | | | | |
|---|---|---|---|---|
| **Variable** | **B** | **S.H** | **t** | **p** |
| $lnGDP_{t-1}$ | 0.888 | 0.065 | 13.553*** | [0.000] |
| $lnRNE_{t}$ | -0.088 | 0.111 | -0.793 | [0.438] |
| $lnRNE_{t-1}$ | 0.211 | 0.125 | 1.684 | [0.109] |
| $lnRNE_{t-2}$ | 0.033 | 0.123 | 0.265 | [0.794] |
| $lnRNE_{t-3}$ | -0.069 | 0.134 | -0.512 | [0.615] |
| $lnRNE_{t-4}$ | -0.241 | 0.127 | -1.901* | [0.073] |
| Fixed Term | 3.524 | 2.034 | 1.733* | [0.099] |
| **F Bounds Test Statistics: H0: There is No Co-Integration.** | | | | |
| F=9.327*** | | Significance | I(0) | I(1) |
| | | 10% | 3.303 | 3.797 |
| | | 5% | 4.090 | 4.663 |
| | | 1% | 6.027 | 6.760 |
| **Long Term Statistics: Dependent Variable lnGDP** | | | | |
| **Variable** | **B** | **S.H** | **t** | **p** |
| lnRNE | -1.372 | 0.353 | -3.888*** | [0.001] |
| Fixed Term | 31.377 | 0.975 | 32.180*** | [0.000] |
| **Error Correction Model and Short-Term Statistics: Dependent Variable ΔlnGDP** | | | | |
| **Variable** | **B** | **S.H** | **t** | **p** |
| $\Delta lnRNE_{t}$ | -0.088 | 0.096 | -0.914 | [0.372] |
| $\Delta lnRNE_{t-1}$ | 0.277 | 0.116 | 2.380** | [0.028] |
| $\Delta lnRNE_{t-2}$ | 0.310 | 0.127 | 2.444** | [0.024] |
| $\Delta lnRNE_{t-3}$ | 0.241 | 0.119 | 2.029* | [0.057] |
| $ECT_{t-1}$ | -0.112 | 0.020 | -5.561*** | [0.000] |
| **Diagnostic Statistics** | | | | |
| **Wald Test** | | F(7, 19)=330.851*** | | [0.000] |
| **Determination** | | $R^2$=0.991 | D.$R^2$=0.987 | |
| **LM Autocorrelation Test** | | $\chi^2$(02)=1.856 | | [0.395] |
| **Breusch-Pagan Heteroscedasticity Test** | | $\chi^2$(06)=2.702 | | [0.845] |
| **Ramsey Reset Test** | | F(1, 18)=0.746 | | [0.399] |
| **Jarque-Berra Normality Test** | | $\chi^2$(02)=8.517** | | [0.014] |

*** (1%), ** (5%), * (10%) Represent Significance at the Significance Level.

When the diagnostic statistics in the table are examined, it is seen that there is no autocorrelation problem in the model at the 10% significance level in line with the LM autocorrelation test ($\chi^2$ (02)=1.856, p>0.10), while there is no heteroscedasticity problem in the model at the 10% significance level in line with the Breusch-Pagan Heteroscedasticity Test. ($\chi^2$(06)=2.702, p>0.10) According to the Ramsey Reset test, no specification error was observed in the model. (F(1, 18)=0.746, p>0.10) Model error terms comply with normal distribution at the 5% significance level. ($\chi^2$(02)=8.517, p>0.05)
When the F limit test statistic is examined to test the cointegration hypothesis to examine the existence of a long-term relationship in the model, it is seen that it exceeds the I(1) critical value for the 1% significance level. (F=9.327> $F_{0.01}$=6.760) In this case, it can be said that the null hypothesis of no cointegration is rejected and the alternative hypothesis of cointegration is accepted. In other words, it can be said that there is a statistically significant cointegration relationship between the variables at the 1% significance level.
When the long-term coefficient is examined, it is seen that a statistically significant and negative coefficient is estimated at the 1% significance level.(β=-0.1372, p<0.01). More clearly, the increase in the percentage of renewable energy in total energy consumption during the period under consideration reduces the Gross Domestic Product. Or similarly, decreasing the percentage of renewable energy in total energy consumption increases GDP.
When the error correction model findings are examined, it is seen that the error correction term is significant at the 1% significance level, negative and less than 1 in absolute value. (ECT=-0.112, p<0.01) In this case, it can be said that the error correction mechanism is functional. In other words, if the adjustment coefficient of long-term deviations is 0.112 throughout the periods, it can be said that it has returned to equilibrium. The size of the adaptation coefficient (1/0.112=8.9) shows that the adaptation of the balance occurred in approximately 9 years.
When the short-term coefficients are examined, it is seen that the variable without lag is statistically insignificant, but the coefficients between 1 and 3 lags are statistically significant and positive. In this case, it can be said that the percentage of renewable consumption in total energy consumption has a delayed positive impact on the Gross Domestic Product. Although these effects are short-term, the effect in the current period is statistically insignificant.
It was decided to apply Toda Yamamoto Causality analysis in order to examine the causal relationships between variables. In this context, information criterion comparisons made to determine the appropriate delay for the VAR model to be established are presented in Table 6.

**Table 6: Information Criteria Comparisons for the VAR Model**

| Number of Delays | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|
| 0 | NA | 0.000035 | -4.597042 | -4.403489 | -4.541306 |
| 1 | 25.35730* | 1.49e-05* | -5.441954* | -5.054848* | -5.330481* |
| 2 | 2.520415 | 0.000018 | -5.260283 | -4.679623 | -5.093074 |
| 3 | 6.962901 | 0.000017 | -5.339418 | -4.565205 | -5.116473 |
| 4 | 4.310725 | 0.000019 | -5.301146 | -4.333380 | -5.022464 |

* denotes optimal value.

When Table 6 is examined, the 1-lag var model is optimal according to all information criteria examined. Within the framework of the Toda Yamamoto procedure, a 2-lag VAR model was established when the degree of the highest order stationary variable was added to the optimal lag ($d_{max}$=1). For the VAR model in question, autocorrelation, heteroscedasticity, normal distribution of error terms and whether the system characteristic roots were located within the unit circle were examined and no deviations in assumptions were observed.
After ensuring the adequacy of the VAR model and analyzing the system established through the VAR model with the Apparently Unrelated Regression Method, the findings of the causality test applied are as shown in Table 7.

**Table 7:Toda Yamamoto Causality Analysis Findings**

| Hypothesis | Test Statistics | p |
|---|---|---|
| lnRNE is not the cause of lnGDP. | $\chi^2$(02)=2.343 | [0.309] |
| lnGDP is not the cause of lnRNE. | $\chi^2$(02)=12.359*** | [0.002] |

*** (1%), ** (5%), * (10%) Represent Significance at the Significance Level..

## 4. Conclusion and Recommendations

The main reason that increases the use of renewable energy is the increase in population. The growth in energy needs has increased the tendency of countries to utilize their existing energy resources and turn to renewable energy. As you know, energy is an important data that not only covers the activities within the countries, but also includes political and military activities and contributes to international connections.

All communities require energy services to meet major human needs and to serve efficient processes. This reason has led countries to research on energy production. The systematic increase in energy requirements in Turkey causes foreign dependency and therefore energy problems. In the period when it can release energy; Saving the unused portion or all of the resulting energy to benefit from it at other times plays a major role in the adoption of renewable energy. When the development rate in the renewable energy sector in recent years is examined, it has shown a significant growth. The connection between the use of renewable energy, one of the main factors in sustainability, and financial development is of great importance.

Within the scope of this study, it is desired to determine the effect of renewable energy consumption on Gross Domestic Product. In this context, the study consists of 30 annual observations between 1991 and 2020. While GDP is the Gross Domestic Product in constant Dollars for the Turkish economy in 2015, RNE represents the percentage of renewable energy consumption in total energy consumption. In the study, it was tested whether the series were stationary or not by Augmented Dickey–Fuller (ADF) unit root test and Phillips–Perron (PP) unit root tests. It is seen that findings consistent with the ADF and PP unit root test findings were obtained for the variables. In this case, it was determined that both variables in the research models were first order stationary (I(1)) variables. There is a statistically significant cointegration relationship between the variables at the 1% significance level.

With the study, the effect of renewable energy consumption in Turkey on the Gross Domestic Product was determined, and it is recommended that the current research can be integrated with other countries in future studies in order to determine the effect of renewable energy consumption on the Gross Domestic Product in a more comprehensive way.

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