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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

The Effect of Renewable Energy on Energy Import Dependence: An Empirical Analysis in Turkey*

Yenilenebilir Enerjinin Enerji İthalat Bağımlılığına Etkisi: Türkiye Üzerine Ampirik Bir Analiz

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Abstract

Energy import dependency has remained one of the most important problems of countries that cannot meet their energy needs from domestic sources from past to present. Countries with insufficient resources in terms of fossil energy sources have met their energy demand through imports. This situation has caused countries to become dependent on external resources. For this reason, Turkey's energy import dependency has increased continuously; according to the data published by EUROSTAT as of 2018, Turkey is foreign-dependent with approximately 74%. This situation has brought the issue of energy supply security to the agenda in Turkey.

For this reason, it is important to examine Turkey's energy import dependency and to propose solutions according to the results obtained. In this study, the effect of renewable energy sources on energy import dependency in Turkey during 1990-2018 was analyzed using the ARDL bounds test approach. The working results have determined that renewable electricity production, GDP per capita, urban population growth, and world natural gas prices have a statistically significant effect on energy import dependency. World oil prices were not statistically significant. As a result, renewable energy production reduces energy import dependency, while the most important determinant is GDP per capita.

Keywords

Energy Import Dependence, Renewable Energy Resources, ARDL Bounds Test Approach

Öz

Enerji ithalat bağımlılığı geçmişten günümüze kendi enerji ihtiyacını yerli kaynaklardan karşılayamayan ülkelerin en önemli sorunlarından biri olarak önemini korumuştur. Enerji ihtiyacını yerli kaynaklardan karşılamayan ve fosil enerji kaynakları bakımından yetersiz kaynağa sahip olan ülkeler enerji talebini ithalatla karşılamışlardır. Bu durum ülkelerin dışa bağımlı hale gelmelerine neden olmuştur. Bundan dolayı Türkiye'nin enerji ithalat bağımlılığı sürekli biçimde artmış, 2018 yılı itibarıyla EUROSTAT'ın yayımladığı verilere göre Türkiye yaklaşık olarak 74% ile dışa bağımlıdır. Bu durum Türkiye'de enerji arz güvenliği sorununu gündeme getirmiştir.

Bu nedenle Türkiye'nin enerji ithalat bağımlılığının incelenmesi ve elde edilen sonuçlara göre çözüm önerileri getirilmesi önem arz etmektedir. Bu çalışmada 1990-2018 döneminde Türkiye'de yenilenebilir enerji kaynaklarının enerji ithalat bağımlılığı üzerine etkisi ARDL sınır testi yaklaşımı kullanılarak analiz edilmiştir. Çalışma sonucunda; yenilebilir elektrik üretimi, kişi başına GSYH, kentsel nüfus artışı ve dünya doğalgaz fiyatlarının enerji ithalat bağımlılığı üzerinde istatistiksel olarak anlamlı etki yaptığı belirlenmiştir. Dünya petrol fiyatları ise istatistiksel olarak anlamlı bulunamamıştır. Sonuç olarak, yenilenebilir enerji üretiminin enerji ithalat bağımlılığını azalttığı ve enerji ithalat bağımlılığının en önemli belirleyicisinin kişi başına GSYH olduğu belirlenmiştir.

Anahtar Kelimeler

Enerji İthalat Bağımlılığı, Yenilenebilir Enerji Kaynakları, ARDL Sınır Testi Yaklaşımı

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Introduction

Energy sources have always had an important place in world history and continue to maintain this importance today. The demand for energy resources has increased significantly compared to the past particularly in regards to the Industrial Revolution. (Yılmaz, 2012: 34). On the other hand, factors such as population growth and population-related high consumption are effective factors in the demand for energy resources. In order to meet the needs of their increasing population and strengthen their economy, countries with sufficient energy resources have caused much environmental destruction by using fossil energy sources intensively without considering their environmental effects (Çıtak and Pala, 2016: 81). Countries with insufficient underground energy resources or production technology have imported their energy resources (Bayrak and Esen, 2014). Since the imported energy sources are fossil-based, they have caused environmental damage. In addition to environmental destruction, the problem of external dependence on energy has also risen in these countries (Uysal et al., 2015: 64). Therefore, import costs have also increased because the increasing energy need with the growth of the country's economy is met through imports (Bayraktutan et al., 2012: 152). This creates a domino effect, increasing the current account deficit and putting pressure on all other economic phenomena (Uysal et al., 2015: 64). In addition to these problems, energy supply security and continuity also pose serious risks, including national security risks, for countries dependent on foreign energy.These countries have shifted to renewable or nuclear energy sources to minimize or eliminate these risks. However, there are high costs and especially security concerns in installing nuclear energy sources (Ergün and Polat, 2012: 38).

Although Turkey is located in the Middle East, it does not have as many energy resources as other Middle Eastern countries.. Due to this situation, Turkey has problems in the supply of energy resources (Yıldırım, 2019: 120). Turkey has become a country that was approximately 74% foreign-dependent in energy in 2018 (EUROSTAT, 2021). Although Turkey is insufficient in terms of fossil energy resources, it is a country with a high potential in terms of renewable energy resources (Gençoğlu, 2002: 57). It is thought that Turkey will utilize this high potential and reduce its dependence on foreign energy. It is also an advantage for Turkey that renewable energy sources are clean and do not emit carbon dioxide into the atmosphere.. But unfortunately, due to the lack of technological infrastructure, renewable energy sources cannot fully utilize their potential. Renewable energy production produced in Turkey is not at a sufficient level in total energy use (Yılmaz, 2012: 50).

The main purpose of this study is to determine the effect of renewable energy production on energy import dependency in Turkey. The secondary aim of the study is to determine the determinants of energy import dependency in Turkey. For this purpose, the research question of the study is: is there a statistically significant relationship between renewable energy production and energy import dependency in Turkey? Depending on this research question, the research hypothesis was formed that there is a statistically significant relationship between renewable energy and energy import dependency in Turkey.

The study was based on the research question and hypothesis given above. The hypothesis is analyzed with the ARDL bounds test which was developed and published by Pesaran et al. in 2001. In this test, the energy import dependency is the dependent variable.

Renewable energy production, gross domestic product per capita, urban population ratio, crude oil prices, and natural gas prices were used as explanatory variables. Working with both l (0) and l (1) data allows reaching reliable and consistent results in small data samples. Obtaining the data used in the established econometric model from reliable sources is important for obtaining consistent results. Therefore, the data used in the study is obtained from EUROSTAT, OECDSTAT, World Bank, and BP sources. When the previous studies are examined, the fact that this study has a wider time data range and the use of population and energy resource prices distinguishes this study from other studies. On the other hand, the increasing energy need and the concerns of foreign dependency on energy to rise to the level of national energy supply security risk in Turkey reveal the importance of this issue.

In this study, first of all, energy sources were mentioned. Then, the development of renewable energy in Turkey and energy import dependency in Turkey are explained with the help of tables and figures. Then, the findings of the analysis obtained from the analysis of the effect of the independent variables on the dependent variable with the time series method and the interpretation of these findings are included in the literature review, the questions researched by the study, and the hypotheses developed based on these questions. Finally, conclusions were drawn based on the results obtained from the analysis.

The Concept of Energy and Its Importance

The energy, generally defined as the ability to do work, is an important input for the continuity of production in an economy. The energy that manifests itself in almost every field is important in terms of heating, continuity of industrial production, transportation, obtaining electricity as a secondary energy source, technology, and sustainability of economic growth (Kocatürk, 2019: 4). Energy has direct or indirect effects on socio-economic structures. Increasing costs in energy in all countries, especially in developing countries, negatively affect economic growth and current account deficit. It also has an important place in the cost part. It is becoming more difficult to obtain fossil energy sources daily and brings high costs (Erol and Güneş, 2017: 341). Energy is closely related to the development of countries and is one of the most important factors that determine the level of welfare. In this respect, energy is important for countries to maintain their development and sustainability in energy. There is a parall between GDP per capita and the amount of energy consumed per capita. For this reason, the amount of energy consumed per capita by countries is taken into account (Çalışkan, 2009: 297).

Energy Resources

Energy sources are divided into primary and secondary energy sources. If the energy source has not undergone any change or transformation, it is expressed as the primary energy source. Resources obtained by converting primary energy resources are called secondary energy resources (Koç and Kaya, 2015: 37). Primary energy sources are also divided into two groups as renewable and non-renewable sources. Examples of non-renewable energy sources are coal, oil, and natural gas. On the other hand, for the energy resources that are considered as renewable, solar, wind, and hydropower energy can be given as examples.

Although non-renewable energy sources can regenerate themselves after they are finished, this process is very long. Considering the renewal rates of renewable energy sources, resources such as oil, coal, nuclear, and natural gas are considered as non-renewable energy resources (Pamir, 2015: 45).

The amount of renewable energy sources may decrease and increase depending on time. However, these are resources that do not change over time and can adapt to changes in environmental conditions (Özsabuncuoğlu and Uğur, 2005, cited by Bingül, 2018: 19). Commonly solar energy, wind energy, hydropower energy, biomass energy, and geothermal energy are used as renewable energy sources (Koç and Kaya, 2015: 40).

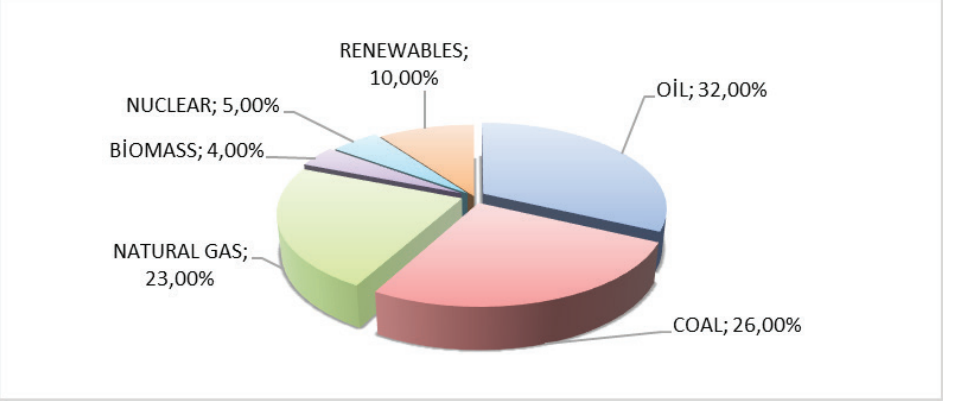

Figure 1. Demand shares of primary energy sources in the world in 2019 by source.
Source: IEA, (2020) by the author with the help of data.

When Figure 1. is examined, in general, it is seen that approximately 86% of the energy demand in the world belongs to oil, coal, natural gas, and nuclear energy, namely non-renewable energy sources. On the other hand, renewable energy sources, hydropower, wind, solar, geothermal, and biomass energy resources, meet approximately 14% of the world's energy demand. In the light of these data, it is seen that there is a large gap between non-renewable energy sources and renewable energy sources regarding energy demand in the world.

Development of Renewable Energy in Turkey

The world is faced with global climate change due to the high use of fossil fuels and has come to a decision-making position. Especially, the energy demands caused by the increasing population and the increasing energy demand of the production sector have caused energy to become a difficult problem. On the other hand, the use of fossil fuels causes severe damage to the environment. Solar, hydroelectric, biomass, geothermal, wind, and marine energy sources are much cleaner and more environmentally friendly than fossil energy sources. They also provide great advantages in terms of sustainable energy. Renewable energy sources, especially solar energy have the potential to meet a huge part of the energy demand. In this sense, although various investments are made in renewable energy both in the world and in Turkey, these investments should be more. It is especially important to develop technology for renewable energy sources (Karabağ et al., 2021: 239). In Table 1, the installed power data in renewable energy in Turkey between the years 2015-2019 are given.

Table 1

Turkey's Renewable Energy (2015-2019) Installed Power Development (Megawatt)

Years / Renewable Energy Types	**2015**	**2016**	**2017**	**2018**	**2019**
Hydroelectric	25.867	26.681	27.273	28.291	28.503
Wind	4.503	5.751	6.516	7.005	7.591
Sun	248	832	3.420	5.062	5.995
Geothermal	623	820	1.063	1.282	1.514
Biomass	370	496	641	818	1.170
Renewable Total	31.611	34.580	38.913	42.458	44.773

Source: TEİAŞ, (2020) by the author with the help of data.

Installed power based on renewable energy sources in Turkey, as can be seen in Table 1, follows a constantly increasing trend. The installed power based on renewable energy sources, 31.611 mw in 2015, reached 44.773 megawatts in 2019. The renewable energy source that had the largest share between 2015 and 2019 was hydroelectric, namely HEPPs. Then, wind energy WPPs, solar energy SPPs, geothermal energy GPPs, and biomass energy are named BPP_S. Since 2015, there has been a decline in HEPPs due to the increased SPPs and WPPs. However, as of 2019, HEPPs had the largest share among renewable energy sources and then WPPs, SPPs, GPPs, and BES come, respectively.

Table 2

Share of Renewable Energy (2015-2019) in Turkey's Total Installed Power (Megawatt)

MW / %	**2015**	**2016**	**2017**	**2018**	**2019**
Turkey's Total Energy Installed Power	73.146	78.497	85.200	88.550	91.267
Renewable Energy Installed Power	31.520	34.449	38.751	42.264	44.395
Share of Renewable Energy in Total Installed Power	43,1	43,9	45,5	47,7	48,6

Source: TEİAŞ, (2019) by the author with the help of data.

When the share of renewable energy installed power in Turkey is examined, in 2015, it is seen that the total installed power is 73.146 MW, and the renewable energy installed power is 31.520 MW. The share of renewable energy in the total installed power is 43.1%. There has been a significant increase compared to the previous year of 2015. When the years after 2015 are examined, it is seen that there is a continuous increase in the share of renewable energy When it comes to 2019, the total installed power is 91.267 MW, renewable energy is 44.395 MW, and the share of renewable energy in the total installed power is 48.6%. These values show that Turkey has made remarkable progress in renewable energy. However, due to the ever-increasing energy demand, Turkey has become dependent on foreign energy sources. Therefore, Turkey needs to gain momentum in renewable energy.

Table 3
Turkey's Renewable Electricity Generation Development (GWh) (2015-2019)

Renewable Energy Types	2015	2016	2017	2018	2019
Hydroelectric	67.145	67.230	58.218	59.938	88.822
Wind	11.652	15.517	17.903	19.949	21.730
Solar	194	1.043	2.889	7.799	9.249
Geothermal	3.424	4.818	6.127	7.431	8.951
Biomass	1.350	1.658	2.124	3.672	3.522
Renewable Total	83.767	90.268	87.263	97.791	132.277
Total Electricity generation	261.783	274.407	297.277	304.801	303.897
share of renewable energy in total electricity generation (%)	32.8	32.9	29.4	32.1	43.5

Source: TEİAŞ, (2020) by the author with the help of data.

When Table 3 is examined, it can be seen that the share of renewable energy in total electricity generation was 32.8% on average between 2015 and 2018. In 2019, this rate increased by 43.5%. While the renewable energy generation of HEPPs with hydroelectric energy was 80% in 2015, it is seen that there has been a decrease since this year. The shares of renewable energy sources in total electricity generation in 2019 are HEPPs are 29%, WPPs are 8%, SPPs are 3%, GPPs are 3%, and BPPs is 1%., respectively.

Energy Import Dependency in Turkey

Energy import dependency means the proportional expression of dependence on imports for the continuity of the mechanisms that need energy in an economy (Sözen, 2009). EUROSTAT expresses the share of energy imported by a country from foreign countries in total energy as energy import dependency. It calculates this ratio as (Energy import dependency = (import-export) / gross usable energy) (EUROSTAT, 2021). In Table 4 below, the energy import dependency ratios of Europe and Turkey for the years 1990-2018 are given.

Table 4
Energy Import Dependency Data for Europe and Turkey for the Years 1990-2018 (%)

Countries / Years	1990	1995	2000	2005	2010	2015	2018
European Union	50.06	52.15	56.28	57.83	55.75	56.01	58.19
Denmark	45.50	33.55	-35.92	-50.62	-15.97	13.16	22.95
Germany	46.53	56.75	59.44	60.74	59.99	62.13	63.44
Estonia	45.50	33.53	33.77	28.04	15.28	10.03	1.01
Greece	61.85	66.47	69.06	68.20	68.58	71.05	70.68
Norway	-435	-640	-723	-661	-515	-576	-554
United Kingdom	2.28	-16	-17	13.36	29.01	37.64	35.51
Turkey	53.55	59.27	65.38	71.68	70.65	77.88	73.79

Source: EUROSTAT, (2021) by the author with the help of data.

When the data in Table 4 given above are examined, it is seen that the European Union is foreign-dependent in energy at the level of 58.19% as of 2018. Looking at the Table 4, it is seen that Estonia has continuously reduced its foreign dependency since 1990 and has the lowest rate. When we look at Germany, which has a strong position and industry in the European Union, this rate is 63.44%. It is seen that there has been an increase over the years in the United Kingdom, which has recently left the European Union, and as of 2018, it is externally dependent on energy at the level of 35.51%. In Greece, Turkey's neighbor, this rate is 70.68%. Although most countries are dependent on external energy, there are also countries that are net exporters of energy, export surplus energy. Norway is a net exporter with a very high rate of -554% in 2018. Despite Turkey's renewable energy investments, energy import dependency has been continuously increasing over the years.And as of 2018, it is highly dependent on foreign energy at the level of 73.79%. In Table 5 below, Turkey's energy balance between 1990 and 2019 is given.

Table 5
Turkey's Energy Balance (1990-2019)

Thousand TEP	**1990**	**2002**	**2017**	**2018**	**2019**	**Change**		
						1990-2019	**2002-2019**	**Direction**
Total Energy Demand (TED) (1)	52.465	77.075	145.305	143.666	144.205	74.859	87.096	↑
Total Domestic Production (2)	25.138	24.430	35.357	39.675	44.821	78.299	83.467	↑
Total Energy Imports	30.663	57.156	124.425	115.792	115.453	276.522	101.996	↑
Domestic Rate of TED (2/1) %	47.913	31.696	24.332	27.616	31.081	-35.2	-2.1	↓

Source: ETKB, (2022) by the author with the help of data.

In Table 5 above, Turkey's general energy balance between 1990-2019 is given. Between 1990 and 2019, the total energy demand increased from 52.465 thousand TEP to 144.205 thousand TEP in 30 years. In the 30 years between 1990 and 2019, domestic production in Turkey increased from 25.138 thousand TEP to 44.821. Likewise, total energy imports increased from 30.663 thousand TEP to 115.5 thousand TEP. On the other hand, when we look at the level of meeting the demand of domestic production, it is seen that it has been in decline over the years and is insufficient to meet the demand. the rate of meeting the energy demand with domestic production as of 2019 is 31.0%. Therefore, based on these data, it would not be wrong to say that Turkey is dependent on energy imports.

Literature Review

Energy import dependency poses significant problems for both developing and developed countries. However, it especially affects developing countries such as Turkey which are insufficient in terms of fossil energy resources. Therefore, various studies have been carried out to determine the determinants of energy import dependency and reduce this dependence with alternative energy sources. When we look at the first studies in this field, it is seen that studies are mostly carried out to determine the determinants of oil imports. These studies can be listed as (in chronological order): Zhao and Wu (2007), Altınay (2007), Jiping and Ping (2008), Ghosh (2009), Uğurlu and Ünsal (2009), Ziramba (2010), Ediger and Berk (2011), Kim and Baek (2013), Solak and Beşkaya (2013), Adewuyi (2016), Öztürk and Arisoy (2016), Marbuah (2017), and Çalışkan and Çakmak (2019).

Çoban and Şahbaz (2011) in their study, in which they used annual data for the period 1990-2007 in Turkey found that R&D expenditures negatively and GNP positively causes a change in energy imports. Üzümcü and Başar (2011) in their study, in which they used quarter annual data for the period 2003-2010 in Turkey; found that there is a negative relationship between current account deficits and economic growth and energy imports. Bilginoğlu and Dumrul (2012) conducted a study to determine the determinants of Turkey's energy imports in the 1960-2008 period and found that the variables of energy production, GNP, the amount of energy used in houses, the ratio of total primary energy supply to GDP are the determinants of energy dependence. Bayramoğlu (2017), in his study using Turkey's 1970-2015 annual data, found that domestic coal production reduces energy dependence. Şişeci (2018) in his study, which deals with Turkey's 2002-2017 period, determined that the GDP and exchange rate are the determinants of energy imports. Fedoseeva and Zeidan (2018), on the other hand, in their study on the period of 1990 to 2015 to determine the determinants of energy imports in Europe, determined that GDP is the most important determinant of energy imports in Europe. Likewise, Kocatürk (2019) stated in his study on Europe and Turkey that there is a strong link between economic growth and energy imports. In their study, Acaravcı and Yıldız (2018) used Turkey data from 1981 to 2015 andthey determined the variables of current account deficit, per capita GNP, relative prices, and gross fixed capital formation are effective on net energy imports.

Studies on crude oil imports and the determinants of energy imports are relatively more than studies on the relationship between renewable energy sources and energy import dependency. Studies on the energy import dependency of renewable energy sources are limited in the literature. Therefore, the examination of this subject will undoubtedly contribute to the literature. Studies on the relationship between renewable energy sources and energy dependency are given below.

In Vaona's 2016 study on the economy of 26 selected countries, the dependent variable is the import of goods and services. The reverse of the percent change in the real effective exchange rate index, customs and other import taxes as a percentage of imports of goods and services, electricity generation from renewable resources, electricity generation from nuclear resources, and electricity generation from gas and coal resources are used as independent variables. The annual data were analyzed using the panel GMM method. As a result of the analysis, it was concluded that renewable energy reduces the import of goods and services.

Dertli and Yinaç (2018), in their study on the Turkish economy, examined the relationship between renewable energy consumption, carbon dioxide emissions, energy imports, and economic growth variables. Johansen co-integration test and Granger causality test were used in the study, in which they used annual data for the period 1990-2014. As a result of the analysis, a co-integration relationship was found between the variables, and they observed that there is a one-way causality running from energy imports to renewable energy.

Dinçer, Yüksel, and Canpolat (2019) examined the relationship between energy imports and renewable energy in their study on E7 country economies. Pedroni panel co-integration and Dumitrescu Hurlin panel causality test were used in the study in which they used annual data for the period 1990-2015. As a result of the analysis, a long-term relationship was found between the variables. However, no causal relationship was found between energy imports and renewable energy use.

Canbay and Pirali (2019) examined the effects of defense expenditures and renewable energy on energy imports in their study on the Turkish economy. They used the ARDL limit test in the study in which they used annual data for the period 1975-2015. As a result of the analysis, a co-integration relationship was found between the variables. They concluded that energy imports affected defense expenditures positively, while renewable energy had a negative effect. They found the coefficient of the error correction model, which shows that the deviations from the short-term are eliminated in the long-term, is negative and statistically significant.

Arslan and Solak (2019) examined the effect of renewable energy on imports in their study on the Turkish economy. They used the Johansen co-integration test and the VAR test in their study, in which they used annual data for the period 1984 to 2017. As a result of the analysis, no co-integration relationship was found between the variables. As a result of VAR impulse-response analysis, they determined that renewable energy increased energy imports.

In his study on the Turkish economy, Asya (2019) examined the effect of renewable energy production and per capita GDP on net energy imports. The ARDL co-integration test was used in the study, in which annual data from 1990 to 2015 was used. As a result of the analysis, it was understood that renewable energy production harms net energy imports and positively affects per capita GDP.

When the literature studies are examined in general, it can be concluded that renewable energy sources reduce energy import dependency, while the most important determinant of energy imports is GDP. When examined from this aspect, it is seen that population and energy prices are not included other empirical analysis. This study included population and energy prices in the analysis model, contributing to the literature.

Data Set, Model, and Findings

In this study, annual data covering the period between 1990-2018 were used. The variables used in the study and the sources from which the data were obtained are given in Table 6.

Table 6
Variables Used in Analysis

Notation	Definition	Type	Source	Calculation Method
EID	Energy Import Dependency	Percentage	EUROSTAT	Energy Import Dependency = (import – export) / gross usable energy
REG	Renewable Electricity Generation	Percentage	OECDSTAT	Renewable Electricity Generation = share of renewable electricity generation in total electricity generation
lnGDPPC	Gross Domestic Product Per Capita	Logarithmic (ln)	Worldbank (WB)	GDP Per Capita = gross domestic product/ mid-year population
UPG	Urban Population Growth	Percentage	Worldbank (WB)	Urban Population Growth (yearly)
lnWCOP	World Crude Oil Price ($)	Logarithmic (ln)	British Petroleum (BP)	US Dollars Per Barrel
lnWNGP	World Natural Gas Price ($)	Logarithmic (ln)	British Petroleum (BP)	USD per million Btu

While creating the data set, it was tried to go back to the oldest period. However, due to the problems in the accessibility of the data in Turkey, the time dimension was determined as the period between 1990 and 2018. Energy import dependency (EID) is the dependent variable; the independent variables are renewable electricity generation (REG), GDP per capita, urban population growth, world crude oil prices (WCOP) and world natural gas prices (WNGP). The linear estimation equation created by considering the variables used in the study is as shown in equation (1). The natural logarithms of GDP per capita (GDPPC), world crude oil prices (WCOP), and world natural gas prices (WNGP) variables were included in the analysis.

$$EID_t = \beta_0 + \beta_1 REG_t + \beta_2 lnGDPPC_t + \beta_3 UPG_t + \beta_4 lnWCOP_t + \beta_5 lnWNGP_t + \varepsilon_t \quad \textbf{(1)}$$

The t index in Equation 1 shows that the series are time series. While β_0 represents the constant term coefficient; β_1, β_2 , β_3, β_4 and β_5 show the slope coefficients and ε_t represents the error term. In this study, time series analysis was used to examine the effect of renewable energy on energy import dependency in Turkey. While performing time series analysis, it is important to determine the stationarity of the data used. Therefore, the stationarity of the variables used in the study was first determined by unit root tests. ADF and PP unit root tests were used in the study. After the stationarity levels of the variables were determined, the co-integration test was applied. In this study, ARDL co-integration test was used.

Unit Root Tests

Dickey and Fuller developed ADF test in 1981 in order to eliminate the possible autocorrelation problem that may be encountered in the DF test. The problem of autocorrelation is overcome by incorporating the variable lags, which are the subject of the analysis, into the model. In the ADF test, the H_O hypothesis, which states that the Yt series contains a unit root, is tested. ADF unit root test hypotheses and model equations are as shown below (Mert and Çağlar, 2019: 99-100).

$H_0: \delta = 0$ (There is a unit root, the series is not stationary).

$H_1: \delta < 0$ (There is no unit root, the series is stationary).

None: $\Delta y_t = \delta y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \varepsilon_t$ **(2)**

Intercept: $\Delta y_t = \mu + \delta y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \varepsilon_t$ **(3)**

Trend and Intercept: $\Delta y_t = \mu + \beta t + \delta y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \varepsilon_t$ **(4)**

Philips and Perron (1988) developed a new non-parametric method. Due to the use of the Philips and Perron test, it is assumed that the distribution of random errors in the Dickey and Fuller unit root test is independent and with constant variance. In other words, it is accepted that there is no autocorrelation between the random errors. This study by Philips and Perron developed this assumption in the Dickey-Fuller test and proposed a new assumption in the distribution of random errors. PP unit root test model equations are as shown below (Sevüktekin and Çınar, 2017: 378).

None: $Y_t = \delta Y_{(t-1)} + \varepsilon_t$ **(5)**

Intercept: $Y_t = \beta_1 + \delta Y_{(t-1)} + \varepsilon_t$ **(6)**

Trend and Intercept: $Y_t = \beta_1 + \delta Y_{(t-1)} + \beta_2 \left(t - \frac{T}{2}\right) + \varepsilon_t$ **(7)**

There are no effects in the DF and ADF unit root tests due to the difference of the standard errors of the error terms that may arise depending on the trend and the effect of the trend on the series. Due to this shortcoming, Philips Perron has developed a new PP unit root test (Tarı, 2016: 400).

Table 7
Unit Root Test Results for Level Values of Series

Variable	ADF TEST		PP TEST	
	Constant	**Constant and Trend**	**Constant**	**Constant and Trend**
EID	-1.328971 (0.6017)	-1.663988 (0.7403)	-1.325322 (0.6035)	-1.640612 (0.7503)
REG	-1.894647 (0.3299)	-1.750339 (0.7013)	-1.818453 (0.3642)	-1.639875 (0.7506)
lnGDPPC	0.404752 (0.9795)	-2.333346 (0.4038)	1.378255 (0.9984)	-2.353689 (0.3938)
UPG	-1.333719 (0.5989)	-1.816488 (0.6686)	-8.092646* (0.0000)	-7.358430* (0.0000)
lnWCOP	-0.899315 (0.7734)	-1.942896 (0.6058)	-0.920382 (0.7665)	-2.099368 (0.5239)
lnWNGP	-1.996325 (0.2866)	-1.767929 (0.6930)	-1.890539 (0.3317)	-1.607273 (0.7642)

Note 1: Values in parentheses are probability values.
Note 2: The calculated values are t statistics.
* Indicates that it is stationary at the 1% significance level.

In Table 7, the ADF and PP unit root tests were obtained using the constant and constant-trend model of the level values of the series the stationarities of which were analyzed. EID, REG and lnGDPPC and lnWCOP and lnWNGP series contain a unit root because they are not stationary at the level. According to the ADF test, UPG series is non-stationary, but according to the PP test, it is stationary at the 1% significance level when both the constant and the constant-trend model are used.

Table 8
Unit Root Test Results for First Differences of Series

Variable	ADF TEST		PP TEST	
	Constant	**Constant and Trend**	**Constant**	**Constant and Trend**
EID	-6.489528* (0.0000)	-7.225786* (0.0000)	-6.359071* (0.0000)	-6.400739* (0.0001)
REG	-6.386021* (0.0000)	-6.400739* (0.0001)	-6.386021* (0.0000)	-6.009624* (0.0002)
lnGDPPC	-5.421612* (0.0001)	-5.409429* (0.0008)	-5.421612* (0.0001)	-5.409255* (0.0008)
lnWCOP	-4.365773* (0.0020)	-4.278892** (0.0114)	-4.293070* (0.0024)	-4.185543** (0.0141)
lnWNGP	-6.435447* (0.0000)	-5.846998** (0.0003)	-6.462291* (0.0000)	-11.91708* (0.0000)

Note 1: Values in parentheses are probability values.
Note 2: The calculated values are t statistics.
* Indicates that it is stationary at the 1% significance level.
** Indicates that it is stationary at the 5% significance level.

Table 8 shows the ADF and PP unit root test results obtained using the constant and constant-trend model of the first difference values of the series the stationarity of which was analyzed. EID, REG, lnGDPPC, and lnWNGP series are stationary at 1% significance level at first difference. But the lnWCOP series, in both tests, it is stationary at a significance level of 1% in the constant model and 5% in the constant-trend model. As a result, it has been decided that the series are stationary at 1(1) difference.

ARDL Bounds Testing Approach

In order to remove the constraint stated in the previous section, ARDL co-integration approach was developed by Paseran et al. (2001). The ARDL model can be applied regardless of whether the variables used in the analysis are l (0) and l (1). ARDL model; although can be applied with variables that become stationary of different degrees, it cannot be used in the case of I (2). For this reason, although any of the variables is I (2), their stationarity is determined by unit root tests. If any of the variables subject to the analysis is 1(2), the analysis cannot be continued (Mert and Çağlar, 2019: 279-284). An unconstrained error correction model is used in the ARDL cointegration approach. On the other hand, the stationarity levels of the variables to be estimated can be both I(0) and I(1). Beyond that, the ARDL model gives better and more reliable results in small samples compared to other cointegration tests (Narayan and Narayan, 2005: 429). The unrestricted error correction model (UECM) created for the ARDL bounds test is given in the equation (8).

$$\begin{aligned}\Delta EID = \alpha_0 &+ \sum_{i=1}^{p} \beta_{1i}\,\Delta EID_{t-i} + \sum_{i=0}^{q_1} \beta_{2i}\,\Delta REG_{t-i} + \sum_{i=0}^{q_2} \beta_{3i}\,\Delta lnGDPPC_{t-i} \\ &+ \sum_{i=0}^{q_3} \beta_{4i}\,\Delta UPG_{t-i} + \sum_{i=0}^{q_4} \beta_{5i}\,\Delta lnWCOP_{t-i} + \sum_{i=0}^{q_5} \beta_{6i}\,\Delta lnWNGP_{t-i} \\ &+ \delta_1 EID_{t-1} + \delta_2 REG_{t-1} + \delta_3 lnGDPPC_{t-1} + \delta_4 UPG_{t-1} + \delta_5 lnWCOP_{t-1} \\ &+ \delta_6 lnWNGP_{t-1} + \varepsilon_t \end{aligned} \quad \textbf{(8)}$$

From the terms given in the equation (8), α_0 shows the constant term, while Δ shows the difference operator, and ε_t denotes error term. After making the regression estimation given in the equation (8), the existence of co-integration is determined by the F statistic. F test hypotheses are given below.

$$H_O: \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0 \quad \text{(No co} - \text{integration).}$$
$$H_1: \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq 0 \quad \text{(There is co} - \text{integration).}$$

Equation (9) given below was formed to estimate the long-run coefficients by considering equation (1) for the study.

$$\begin{aligned}EID = \alpha_0 &+ \sum_{i=1}^{p} a_{1i}\, EID_{t-i} + \sum_{i=0}^{q_1} a_{2i}\, REG_{t-i} + \sum_{i=0}^{q_2} a_{3i}\, lnGDPPC_{t-i} \\ &+ \sum_{i=0}^{q_3} a_{4i}\, UPG_{t-i} + \sum_{i=0}^{q_4} a_{5i}\, lnWCOP_{t-i} + \sum_{i=0}^{q_5} a_{6i}\, lnWNGP_{t-i} \\ &+ \varepsilon_t \end{aligned} \quad \textbf{(9)}$$

Finally, the short-run coefficients are estimated. Error correction mechanism is used for this. The equation (10) created for the error correction model is given below.

$$\Delta EID = \alpha_0 + \sigma_1 ECM_{t-1} + \sum_{i=1}^{p} \sigma_{2i}\, \Delta EID_{t-i} + \sum_{i=0}^{q_1} \sigma_{3i}\, \Delta REG_{t-i} + \sum_{i=0}^{q_2} \sigma_{4i}\, \Delta lnGDPPC + \sum_{i=0}^{q_3} \sigma_{5i}\, \Delta UPG_{t-i} + \sum_{i=0}^{q_4} \sigma_{6i}\, \Delta lnWCOP_{t-i} + \sum_{i=0}^{q_5} \sigma_{7i}\, \Delta lnWNGP_{t-i} \quad \textbf{(10)}$$

The term ECM_{t-1} given in the equation represents the error correction term. This error correction term is expected to be negative and significant. Error correction mechanism means that short-run imbalances will be corrected in the long-run.

In applying the ARDL bounds test, appropriate lag lengths are first determined. EID dependent variable; the maximum lag length was determined as 2 for the ARDL (p, q1, q2, q3 q4, q5) model estimation, with REG, lnGDPPC, UPG, lnWCOP and lnWNGP as explanatory variables, and the analysis was started based on the AIC information criterion. The model automatically found the appropriate lag length was automatically found as (1,1,0,2,0,0) by the model.

Table 9

ARDL Bounds Test Results

H_0: No Co-Integration			
	α	**I (0) ***	**I (1) ***
F=5.462439	%10	2.578	3.858
K=5	%5	3.125	4.608
	%1	4.537	6.37
	α	**I (0)**	**I (1)**
t=-4.286253	%10	-2.57	-3.86
	%5	-2.86	-4.19
	%2.5	-3.13	-4.46
	%1	-3.43	-4.79

*The critical values produced by Narayan (2005) for n=30.

When the ARDL bounds test results are examined in Table 9, it is seen that the F bound test is 5.462439. This value is greater than the 5% and 10% error levels of the upper critical I(1) values produced by Narayan (2005). Therefore, the HO hypothesis of "no cointegration" was rejected. Therefore, according to the F test, the series are co-integrated at the 5% significance level. Looking at the t test, it is seen that the t value is -4.286253. Since this value is greater than the error levels of the 5% and 10% upper critical values in absolute value, according to both the F test and the t test, the series are co-integrated at the 5% significance level. After it has been determined that the series are co-integrated, they move together in the long run, and long-run predictions are made. The long-run results are given in Table 10 below.

Table 10
Long-Run Results

Variables	Coefficient	St. Error	t-Statistic	P (Probability)
REG	-0.262284*	0.085603	-3.063944	0.0070
lnGDPPC	21.41023*	3.567327	6.001755	0.0000
UPG	8.302404***	4.382182	1.894582	0.0753
lnWCOP	-0.915633	1.374531	-0.666142	0.5143
lnWNGP	4.370648**	1.523593	2.868644	0.0106
R Squared : 0.975629			Akaike info criterion	:3.903704
Adjusted R Squared : 0.962727			Schwarz criterion	:4.383644
F-Statistic :75.61679*			Hannan-Quinn criterion	:4.046416
F-Statistic (Probability): 0.000000			Durbin-Watson stat	:2.199935

* Indicates that it is stationary at the 1% significance level.
** Indicates that it is stationary at the 5% significance level.
*** Indicates that it is stationary at the 10% significance level.

When Table 10 is examined, a negative and statistically significant relationship was determined between the REG variable and EID; it was determined that there is a positive and statistically significant relationship between lnGDPPC, UPG and lnWNGP and EID. On the other hand, no statistically significant relationship was found between lnWCOP and EID. On the other hand, in Table 11 below, the error correction model is estimated to determine whether short-run imbalances are eliminated in the long-run

Table 11
Error Correction Model Results

Variables	Coefficient	Std. Error	t-Statistics	P(Probability)
C	-120.0601*	18.56916	-6.465562	0.0000
D(REG)	-0.026332	0.052323	-0.503256	0.6212
D(UPG)	-2.566558	4.755695	-0.539681	0.5964
D(UPG (-1))	10.17392	3.156713	3.222948	0.0050
$\mathbf{EC_{t-1}}$	-0.846358*	0.129957	-6.512621	0.0000
		α	**L (0)**	**l (1)**
t= **-6.51262**1				
		%10	-2.57	-3.86
		%5	-2.86	-4.19
		%2.5	-3.13	-4.46
		%1	-3.43	-4.79

* Indicates that it is stationary at the 1% significance level.

When the results are examined, it is seen that the error correction coefficient was calculated as $\boldsymbol{EC_{t-1}}$=-0.846358. This calculated value should be negative and statistically significant. When $\boldsymbol{EC_{t-1}}$=-0.846358 was examined, it was found to be negative and statistically significant. Looking at the t test, it is seen that this value is calculated as t =-6.512621. Therefore, the error correction coefficient is statistically significant. The short-run imbalances in the model will reach the long-run equilibrium after 1/0.84=1.19 years. Finally, diagnostic and stability tests of the predicted model were performed. Table 12 below shows the diagnostic test results for the predicted model.

Table 12

Diagnostic Test Results

Diagnostic Tests		
Tests	**F (Calculated)**	**P (Probability) ***
Heteroskedasticity (Breusch-Pagan-Godfrey)	1.425689	0.2526
Model Specification (Ramsey-Reset)	0.269291	0.7911
Serial Correlation (Breusch-Godfrey)	0.984153	0.3966
Normality (Jarque-Bera)	0.346352	0.840990

*Test probability values greater than 0.05 indicate that the assumptions are met.

When the diagnostic test results were examined, no problem was detected in all diagnostic tests; it has been determined that the model does not have Heteroskedasticity, model specification, serial correlation, and normality problems. In order to determine whether the estimated parameters outside of these diagnostic tests are stable or not, the cusum and cusumQ graphs are given below. When both graphs are examined, parameter estimates were found to be within 5% confidence limits, and no problems were detected. Therefore, the estimated parameters are stable.

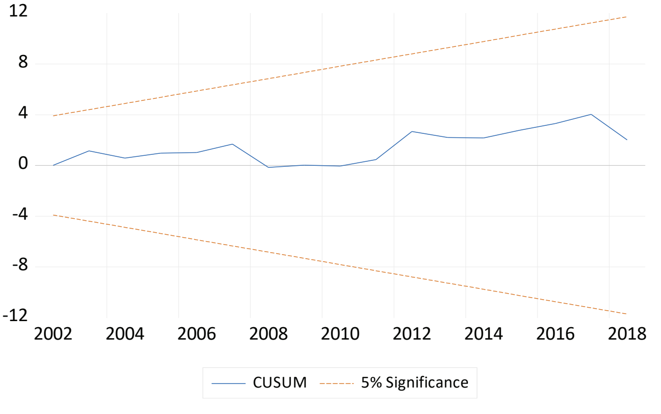

Figure 2. CUSUM Chart

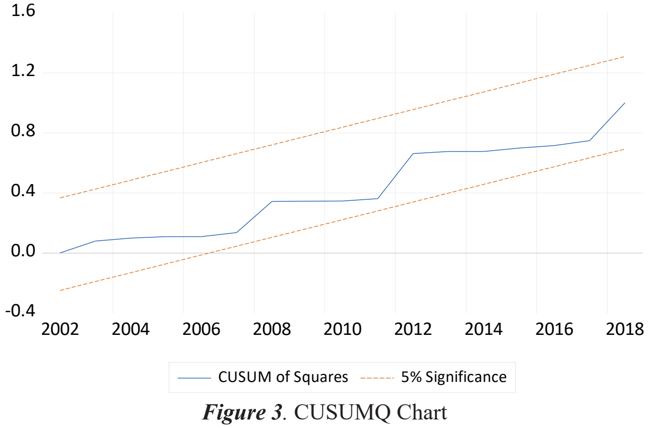

Figure 3. CUSUMQ Chart

Robustness Check

In this title, it was tested whether the results of the econometric model established in the study were not found by chance and whether they had stable coefficients. Different techniques are used in the literature, and in this study, oil prices, which were added to the model as a control variable, were excluded from the model, and the analysis was repeated.

Table 13
ARDL Bounds Test and Diagnostic Test Results

Maximum Lag	Akaike Info Criterion (2)	
ARDL Model	Constand (1,1,0,2,0)	
F-Statistics	**6.695080**	
k	4	
Critical Values		
α	**I (0)**	**I (1)**
10%	2.752	3.994
5%	3.354	4.774
1%	4.768	6.670
Diagnostic Tests		
Tests	**F (Calculated)**	**P (Probability)**
Heteroskedasticity (Harvey)	1.885334	0.1257
Model Specification (Ramsey-Reset)	0.560213	0.5826
Serial Correlation (Breusch-Godfrey)	1.193984	0.3286
Normality (Jarque-Bera)	0.569989	0.7520

When Table 13 was examined, it was determined that the series were co-integrated and the result found was the same as the result in Table 12 although there were slight differences.

Table 14
Long-Run and Error Correction Model Results

Variables	**Coefficient**	**St. Error**	**t-Statistic**	**P (Probability)**
REG	-0.248994	0.086358	-2.883263	0.0099
lnGDPPC	19.33653	1.963088	9.850055	0.0000
UPG	8.433291	4.567965	1.846181	0.0814
lnWNGP	3.951621	1.423690	2.775619	0.0125
Error Correction Model Results				
Variables	**Coefficient**	**St. Error**	**t-Statistic**	**P (Probability)**
$\mathbf{EC_{t-1}}$	-0.800333	0.125122	-6.396435	0.0000
R Squared: 0.975048 Adjusted R Squared: 0.963958 F Statistic: 87.92325 F Statistic (Probability): 0.000000		Akaike Info Criterion: 3.853190 Schwarz Criterion: 4.285136 Hannan-Quinn Criterion: 3.981630 Durbin-Watson Stat: 2.279872		

When Table 14 is examined, small marginal differences are detected in the long-term coefficients. However, it has been observed that it is largely the same with the results in Table 10. Based on these results, it has been determined that the model is stable and has stable long-term coefficients when oil prices are subtracted from the model established in the study.

Conclusion

Energy sources have maintained their importance since the early days they were used. Due to human beings' needs and unlimited demands, the energy demand has increased continuously. This increase has brought about high consumption of energy resources. Especially the developments in the industrial field and the increasing population have increased the consumption of energy resources to the highest level. There are countries that provide high energy consumption from domestic sources. However, countries like Turkey, which are poor in terms of underground energy resources, face many difficulties in meeting their increasing energy consumption with domestic resources. These countries, which could not meet their energy consumption with domestic resources, started to supply their energy deficit. These initiatives have made the countries that are insufficient in terms of energy resources dependent on external energy. At the same time, energy supply security has become one of the most important problems of these countries. These countries are dependent on foreign energy in the field of energy. Although they have implemented policies such as energy resource diversity and energy efficiency, it is clear that such policies alone are not sufficient.

On the other hand, the increasing use of fossil energy resources has caused serious damage to nature. Although it is said that necessary precautions are taken in terms of the environment in the countries using fossil energy sources, the effects of climate change experienced show that the opposite is true. Renewable energy sources stand out as the best alternative energy source in overcoming all these problems and helping countries with insufficient fossil resources to meet their energy needs. Renewable energy sources are distinguished from other energy sources because they are a clean and domestic resource.

In this study, the effect of renewable energy on Turkey's energy import dependency has been tried to be determined. Turkey's energy import dependency, renewable electricity production, per capita gross domestic product, urban population growth, world crude oil prices, and world natural gas prices, a total of 29 years between 1990 and 2018 were used in the analysis. In the study, firstly, the stationarity levels of the series were determined with the ADF and PP unit root tests to determine the stationarity of the series. Then, ARDL co-integration test was applied. As a result of ARDL bounds test, a co-integration relationship was determined between the variables. In other words, it was concluded that the series move together in the long run.

It has been determined that renewable energy is the determinant of energy import dependency in Turkey. This result is similar to the studies of Asya (2019), Canbay and Pirali (2019). It has been determined that per capita gross domestic product is the most important determinant of energy import dependency in Turkey. It has been found that the rate of urbanization is the second biggest determinant of energy import dependency in Turkey. In this context, similar results were obtained by Bayramoğlu (2017). On the other hand, Jiping and Ping (2008) on the Chinese economy, Marbuah (2017) on the economy of Ghana, and Adewuyi (2016) on the Nigerian economy determined that population is among the main determinants of oil imports. This study showed that the second main determinant of energy import dependency is urbanization and population growth. It has been concluded that world crude oil prices are not a determinant of energy import dependency in Turkey. Altınay (2007) and Öztürk and Arisoy (2016) in their study in Turkey in which they used crude oil imports as the dependent variable, concluded that the crude oil price is not flexible in the long and short run. On the other hand, Solak and Beşkaya (2013), in their study on using net oil imports in Turkey, determined that oil prices do not have an effect on net oil imports. Although energy import dependency has been used in our study, it is possible to say that similar results have been obtained. It has been determined that world natural gas prices are the determinants of energy import dependency in Turkey.

Finally, the short-run coefficients of the variables and the error correction term are estimated. As a result of the analysis, the error term was found to be $\boldsymbol{EC_{t-1}}$ = -0.84. It was determined that the error term was statistically significant and negative. Therefore, it has been determined that the short-run imbalances in the model will be eliminated in the long-run. As a result, it has been concluded that renewable energy is effective on Turkey's energy import dependency.

This study was conducted under some limitations. It has been tried to reach a wider data range as a data set. However, since the data between 1990 and 2018 were reached, the study was limited to the years between 1990–2018. In future studies, it will be possible to work with wider data sets as it will be possible to reach a wider data range. In this study, it was considered to use co-integration tests that take into account the structural break. However, the ARDL bounds test was used because the data size is small and the urban population data used in the model is stationary at the level. In future studies, the data size can be larger, and a different variables can be used to represent the urban population data so that the study can be developed with different methods. The study was carried out with the data set of Turkey. In future studies, data sets belonging to different countries or country groups can be studied. Thus, it is possible to compare the regional differences in the results.

Turkey has recently turned to renewable energy sources to a large extent. Electric energy obtained by hydroelectric energy has the largest share among renewable energy sources. However, Turkey benefits from solar energy well below its potential. Turkey is geographically in a very good position in terms of solar energy. Turkey should benefit from all its potential in the light of correct planning when generating electrical energy from other renewable energy sources, especially solar energy. Renewable energy sources should be encouraged. Because as seen in the analysis of the study, renewable energy sources have a reducing effect on energy import dependency. Therefore, more use of renewable energy sources is required.

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