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A PUBLIC ENERGY POLICY PROPOSAL FOR TURKIYE IN THE LIGHT OF ECONOMETRIC FINDINGS

Metin DOĞAN [1]

ABSTRACT

Energy supply security is one of the most debated issues in the energy sector in recent years. Although there is no clear agreed definition of energy supply security, there are determinations that energy should be cheap, sustainable, continuous, and available in order to ensure energy supply security. The wars and political instabilities in the region where Turkey is located have caused the issue of energy supply security to gain importance in recent years. Therefore, Turkey continues to work in areas such as oil and natural gas exploration and production, coal extraction, increasing renewable energy supply, ensuring energy efficiency, and nuclear power generation to ensure energy supply security. However, although these methods such as oil and natural gas exploration and production are useful in terms of energy supply security, they increase Turkey's fossil fuel dependency and this situation weakens Turkey's efforts to combat climate change, which is one of Turkey's goals. In this study, the impact of coal, natural gas, oil, and renewable energy production on energy dependence, which is among the most important causes of energy supply security, between 1987-2020 is analyzed by the ARDL cointegration test method. In addition, the empirical analysis is concluded by using the Toda-Yamamoto causality test to observe the causality relationship between the variables. The findings of the analysis lead to the conclusion that Turkey's domestic energy production should be restructured according to environmental priorities.

Keywords: Energy supply security, Primary energy supply, Climate change, Energy dependence, ARDL cointegration test, Toda-Yamamoto causality test

EKONOMETRİK BULGULAR IŞIĞINDA TÜRKİYE İÇİN BİR KAMUSAL ENERJİ POLİTİKASI ÖNERİSİ

ÖZ

Enerji arz güvenliği, enerji sektöründe son yıllarda en çok tartışılan konulardan biridir. Enerji arz güvenliği için üzerinde anlaşılmış net bir tanım olmasa da enerji arz güvenliğinin sağlanması için enerjinin ucuz, sürdürülebilir, sürekli ve elde edilebilir olması gerektiği yönünde tespitler vardır. Türkiye'nin de yer aldığı bölgede ortaya çıkan savaşlar ve politik istikrarsızlıklar, enerji arz güvenliği konusunun son yıllarda önem kazanmasına neden olmuştur. Türkiye bu yüzden enerji arz güvenliğinin sağlanması için petrol ve doğalgaz arama ve üretme, kömür çıkartımı, yenilenebilir enerji arzının artırılması, enerji verimliliği sağlanması, nükleer güç üretimi gibi alanlarda çalışmalarına devam etmektedir. Ancak bu sayılan yöntemler arasında yer alan petrol ve doğalgaz arama ve üretme gibi yöntemler her ne kadar enerji arz güvenliği konusunda yararlı olsa da Türkiye'nin fosil yakıt bağımlılığını artırmakta ve bu durum Türkiye'nin hedeflerinden biri olan iklim değişikliği ile mücadele konusunda yaptığı çalışmaları zafiyete uğratmaktadır. Bu çalışmada 1987-2020 yılları arasında kömür, doğal gaz, petrol ve yenilenebilir enerji üretiminin enerji arz güvenliğinin en önemli nedenleri arasında yer alan enerji bağımlılığına etkisi ARDL sınır testi yöntemiyle analiz edilmiştir. Ayrıca değişkenler arasında nedensellik ilişkisinin görülebilmesi için Toda-Yamamoto nedensellik testi kullanılarak ampirik analiz sonuçlandırılmıştır. Analizden elde bulgular Türkiye'nin yerel enerji üretiminin çevresel önceliklere göre yeniden yapılandırılması gerektiği sonucuna ulaşılmasını sağlamaktadır.

Anahtar Kelimeler: Enerji arz güvenliği, Birincil enerji arzı, İklim değişikliği, Enerji bağımlılığı, ARDL eşbütünleşme testi, Toda-Yamamoto nedensellik testi

[1]Dr., metindogan6216@gmail.com, ORCID: 0000-0002-5832-7212
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INTRODUCTION

The climate crisis is a phenomenon that brings along many economic, social, and environmental problems due to global warming. One of the most prominent methods in the energy sector to combat the climate crisis is to increase the supply of renewable energy. However, policies related to energy supply security sometimes cause the issue of increasing renewable energy supply to take second place.

While Turkey is committed to tackling the climate crisis, it also continues to work for energy supply security. In this context, in addition to increasing renewable energy supply, many measures have been taken, including oil and natural gas exploration and production, exploration and production of coal mines, the establishment of nuclear power plants, increasing energy efficiency, diversification of imported primary energy sources and securing energy routes.

Renewable energy and energy efficiency, which are local, sustainable, and affordable, can be an important method in Turkey's fight against the climate crisis and in terms of energy supply security. Resources such as oil, natural gas, and coal are energy sources in the fossil fuel group, and these are considered non-clean energy sources. The existence of reserves of these energy resources in land and marine areas is known. For this reason, Turkey has prioritized oil and natural gas exploration and production in recent years. The last method, nuclear energy, is still under debate as to whether it should be considered a clean energy source. Nuclear energy has been criticized for the risk of damage to the environment by maintaining the activity of final wastes for many years, the costly construction of nuclear power plants and reactors, and the risk to energy supply security by creating new dependency relations.

This study analyzes the impact of oil, natural gas, renewable energy, and coal, which are the primary energy supply sources in Turkey, on energy dependence, which is one of the most important elements of energy supply security. Nuclear power plants are excluded from the analysis since they have not yet started production in Turkey. In the study covering the period between 1987-2020, the ARDL bounds test is first used. After this test, the Toda-Yamamoto test is used to investigate the causality relationship between variables. The findings obtained from the analysis are expected to be useful for Turkey's new policies in areas such as energy supply security and climate change and to contribute to the literature.

1. A Framework for Energy Supply Security

Energy is not only one of the basic inputs of production but also a necessity for a society to reach a modern level of welfare. Energy is therefore of vital importance for all countries today. The unbalanced distribution of energy across the geography of the earth and the problems in energy supply are the main reasons for the emergence of energy supply security[23]. Founded after the 1973 Oil Crisis, the International Energy Agency (IEA) defines energy security as the ability to supply energy at an affordable price without interruption (IEA, 2019). According to Erdal (2015), energy supply security is defined as energy that can be obtained from sustainable and reliable sources and at affordable prices. In Pamir's (2017) study, these definitions are slightly improved. According to Pamir, energy security is defined as "the ability to obtain energy from sufficient, affordable, reliable, timely, clean and diversified sources, from domestic sources as much as possible, uninterrupted and high quality".

Costantini et al. (2007) stated that energy security, as defined above, has different economic, social, environmental, and long- and short-term aspects. The economic aspect of energy security arises when the energy supply is physically depleted or interrupted for any reason. This would sharply raise energy prices, leading to a contraction in the purchasing power of consumers. Instability of the energy supply and price-based problems in the energy supply also entail social risks. A contraction in energy supplies could lead to social conflicts, as in the case of the yellow vest protests. Another concern related to energy supply is the environment. Energy-related pollution damages ecosystems. Finally, the definition of energy security can be seen from a short-term perspective or a long-term perspective. In the short term, it is about the devastating effects of an unexpected interruption in supply or a price spike, while in the long term, it is more about the availability of sufficient energy to enable stable and sustainable economic development. Similarly, according to the IEA (2019), energy security focuses on responding to shocks in the energy market in the short term, while in the long term, it focuses on making timely investments for the supply of energy by assessing economic and

[2] In 1973, the embargo imposed by many oil-producing countries against countries that supported Israel in the Arab-Israeli War increased oil prices, which had been stable until then. Oil, which had been selling for an average of US$ 3.5 in 1972, started to sell for US$ 12 as a result of this embargo, resulting in a 7% reduction in the global oil supply. This war also led to the establishment of the IEA. Although the main objective of the IEA was initially to ensure the security of the oil supply of its member countries, this objective gradually evolved into a more general view of energy security. Source: Pamir, 2017, p.48

2 Various risks to energy supply security can affect all countries. Global fossil fuel production has not yet reached the point of exhaustion. However, a reduction in fossil fuel supply in the coming years will bring new problems. The energy sector is a sector that both affects and is affected by the climate crisis. Therefore, energy supply security is directly related to the climate crisis. As in the case of the explosions in Nord Stream 1 and Nord Stream 2, which were used to transport Russian natural gas in 2022, energy supply security can be affected by all kinds of social, and political risks and attacks. Source: Özdemir et al., 2017, p.216

[3] While the reference to affordability is intended to draw attention to the possible negative welfare effects of sudden large energy price increases, it is also important in the context of lack of access to energy, especially for lower-income groups of the population. Households choose between energy options based on fuel accessibility and affordability, household socio-economic characteristics and attitudes, and the qualities of different fuels. Lack of access means that energy needs are not met, or traditional fuels are used, both of which lead to reduced energy security. Where commercial energy services and electricity are available, income emerges as the main factor influencing household fuel choice. Source: Costantini et al., 2007, p.211

environmental factors. Therefore, different policies should be formulated for the security of the energy supply in the short and long run.

Another important issue in terms of energy supply security is the components of energy supply security. The first of these four components is the availability of energy. If energy is available, the consumer will be able to access energy without difficulty. The second component is the affordability of energy[4]. This component implies that there should be stable and predictable prices in the energy market. The third component, reliability, is crucial for ensuring the security of the energy supply. This is because this component implies continuity in energy flow. A break in the energy flow will cause disruptions in both production and social life. The last component, sustainability, has become one of the elements of energy supply security due to the growing environmental problems in recent years. Sustainability of energy is an important component for the country to avoid the costs associated with climate change (Ursavaş and Yıldırım, 2017, pp.58-59).

2. Energy Supply Security in Turkey

Security of energy supply has economic, social, and environmental aspects. In addition, the risks that cause energy supply security may differ from country to country. Turkey may face various risks in terms of energy supply security due to its geopolitical position, macroeconomic outlook, and environmental problems. The first of these risks are related to the increasing energy consumption in recent years. Although Turkey has a 1% share in global energy consumption, its energy demand has increased more than the global average due to its young and dynamic population. While global energy demand increased by 1.8% between 2005 and 2015, this rate was 4.4% in Turkey. In OECD (Organization for Economic Cooperation and Development) countries, energy demand is decreasing by 0.3% per year. The size of Turkey's energy demand makes it the fastest-growing energy demand among OECD countries (SBB, 2018, p.20).

The second risk is Turkey's dependence on fossil fuels for energy. One of the main causes of climate change is the use of fossil fuels. In addition to the environmental consequences of fossil fuel use, the depletion of fossil fuels will create a serious problem in the energy supply. Therefore, fossil fuel dependency is also a serious risk for Turkey (Yılmaz, 2022, pp.96-97).

[4] This could also be an opportunity for Turkey. Many developed countries have made progress in terms of energy intensity but have started to slow down in reducing energy intensity. In this sense, Turkey may have an advantage over developed countries in reducing energy intensity. Source: Duman Altan and Sağbaş, 2020, p.9-10

Another important risk for Turkey is energy dependence. As a country whose energy demand is increasing day by day, Turkey does not have sufficient domestic energy production and therefore purchases the energy it needs from energy-importing countries. This situation leads to the emergence of the problem of external dependence on energy. In addition, Turkey spends billions of dollars of resources every year due to energy imports. In the period covering the years 2010-2019, Turkey allocated an average of USD 45 billion of its resources (a share between 13% and 25% of total imports for the specified period) to energy supply each year (İnançlı and Akı, 2022, p.123).

Wars and other geopolitical risks, such as the Ukraine-Russia War, seriously affect Turkey's energy security. There are also various risks arising from the scarcity of energy investments. Many empirical analyses have shown that macroeconomic variables are related to energy supply security. This situation also affects the investments made in the field of energy and the desired level of domestic energy production cannot be reached. Finally, the high energy intensity ratio, which is a tool used to measure energy efficiency, is seen as another risk for Turkey's energy supply security (Yılmaz, 2022, pp.98-99).

As can be understood from the above explanations, Turkey is one of the high-risk countries in terms of energy supply security. For this reason, energy supply security has an important place in the National Energy and Mining Policy included in the 11th Development Plan covering the period between 2018-2023. As stated in the 11th Development Plan, the National Energy and Mining Policy is built on three important strategies. These are energy supply security, predictable markets and domestication. Security of energy supply is one of the most important strategies for Turkey's energy policy. Security of energy supply aims to diversify the primary energy resources used in energy production (renewable energy, coal production, etc.), reduce external dependency by increasing primary energy production and use the resources obtained effectively and efficiently. The second strategy, domestication, is indeed a strategy related to energy supply security. The prominent resources in the domestication strategy are renewable and nuclear energy. The last important strategy in terms of the National Energy and Mining Policy, predictable markets, is to make investments in energy easier and faster. This strategy is actually complementary to the energy supply security and localization strategies. This strategy aims to increase the share of local supply in energy production (SBB, 2018, p.20).

In the 11th Development Plan, it is stated that various measures that can be considered within the scope of policies related to energy supply security and domestication strategies should be implemented. These measures include the exploration and production of local fossil fuel resources, diversification of fossil fuel resources, and reducing energy consumption through energy efficiency. When these measures are analyzed separately, the first issue that Turkey prioritized in terms of energy supply security was natural gas and oil exploration and extraction. To achieve this, the Petroleum Law provided various incentives to increase the attractiveness of natural gas and oil extraction. Another method Turkey has used is to change the source and route of imported gas. Thus, while the dependence on Russia for natural gas has decreased, new commercial agreements have been made with countries such as Iran and Azerbaijan. In addition, activities are underway to increase energy storage capacity, which is considered important in terms of supply security (IEA, 2021, p.11-12).

Another important element that Turkey considers important for energy security is increasing energy efficiency. According to the National Energy Efficiency Action Plan, energy efficiency is an important method for ensuring energy supply security. In this context, it is planned to reduce primary energy consumption by around 14% between the specified years (2017-2023) by implementing policies to increase energy efficiency in many sectors, especially buildings and services, energy, transportation, industry and technology, agriculture (YPK, 2017). In addition, Turkey is also considering local energy sources such as renewable energy, nuclear[5] , and coal to increase local production (IEA, 2021, p.12).

3. Literature

Marques et al. (2010) used panel data approach to examine the factors affecting the motivation to use renewable energy. In the study, where the sample period was determined as 1990-2006, it was observed that traditional energy sources and carbon emissions restrict the use of renewable energy, while targets to reduce energy dependence encourage the use of renewable energy.

Erdal (2015) developed 4 different indices to measure energy supply security in Turkey. These indices were then analyzed with a model between 1970-2009 using Granger Causality and Johansen Cointegration tests. The independent variables in this model are oil prices, total primary energy supply, per capita energy consumption, share of renewable energy sources and carbon dioxide emissions. As a result of the tests, renewable energy has a positive impact on energy supply security. The second independent variable, the increase in per capita

[5] In addition to environmental concerns, there are criticisms that nuclear power plants are not the right source for energy supply security in Turkey. The costly nature of nuclear power plants, the fact that they do not provide Turkey with additional technological opportunities, and the possibility of being attacked lead to criticism that nuclear is an inefficient investment for Turkey. Source: Damar, 2022, p.11

energy consumption, is identified as a risk factor for energy supply security. The third independent variable, the amount of fossil fuel emissions, was found to be another risk factor for energy supply security. Total primary energy supply, the last variable with significant results, is an important factor for energy supply security. A significant increase in domestic energy supply will lead to an increase in energy supply security.

Chalvatzis and Ioannidis (2017) conducted an analysis for the European Union using Shannon Wiener and Herfindahl-Hirschman indexes. The findings obtained by using these indexes show that there has been an improvement in energy supply diversity in the EU since the 1990s. Moreover, renewable energy makes a significant contribution to the domestic production of energy.

Ursavaş and Yıldırım (2017) analyzed the relationship between energy supply security risk and macroeconomic variables between 1980 and 2012. In this model using the Toda-Yamamato causality test, unidirectional Granger causality was found from energy supply security risk to economic growth, inflation and current account deficit variables, while no relationship could be established between employment and energy supply security risk, the other variable in the model.

Although the literature often refers to the role of renewable energy in energy supply security, some studies emphasize the importance of energy diversity. The study by Ruble (2017) is one of them. The simulation in this study indicates that the EU's natural gas exports will increase between 2021 and 2042. Therefore, it was concluded that alternative natural gas transportation lines are necessary for energy supply security.

Gökgöz and Güvercin (2018) conducted an analysis for selected EU countries between 2004-2014. In this study, it is empirically demonstrated that renewable energy reduces energy dependence. Then, using data envelopment analysis, it was observed that there was an increase in renewable energy efficiency and productivity in EU countries.

Nyga-Łukaszewska et al (2020) focus on natural gas and coal markets through heating and electricity generation. Between 2011 and 2019, cointegration analysis was used in this study for the case of Poland. According to the results, it is observed that the coal market is more dependent on imports in electricity generation in Poland, while natural gas is more dependent on imports in heating. Therefore, different policy measures should be applied to different markets when discussing energy security.

Gökce and Babacanoğlu (2020) conducted an analysis covering the period between 1980 and 2016. In the study using the Vector Error Correction Model (VECM), the energy supply security risk index is the dependent variable. The independent variables are economic growth, investments, inflation, current account deficit and employment. According to the findings of the study, there is a bidirectional causality relationship between the dependent variable and the independent variables economic growth, investments, inflation, and current account deficit, while there is a unidirectional causality relationship between the other independent variable employment and the dependent variable in both the short and long run.

In the study prepared by Birol (2021), it is aimed to measure the energy supply security in EU countries and Turkey according to 2015 data and to make a comparative analysis. Herfindahl-Hirschman, Shannon Diversity Index and Shannon Weiner-Neumann indices, which are frequently used in the literature, were used to measure energy supply security. According to the analysis, when a comparison is made with EU countries in natural gas supply, it is seen that Turkey's energy supply security is among the high-risk countries.

Park and Bae (2021) constructed two indexes in their recent study. These indexes were used to assess South Korea's energy supply security between 1991 and 2018. This study shows that energy diversification is not enough to achieve energy security.

Kök and Nazlıoğlu (2022) conducted an analysis using Toda-Yamamato and Fourier Toda-Yamamato causality tests for BRICS-T countries including Turkey. In the analysis covering the period between 1994-2018, the relationships between the international energy security risk index, Brent oil prices and the stock markets of the countries included in the analysis were analyzed. The results obtained from the analysis for Turkey indicate that there is a causality from equity shares to energy security risk score, bidirectional causality from an energy security risk to oil price, and causality from an energy security risk score to the stock market. The results revealed that risk and unpredictability in financial markets have a negative impact on energy supply security.

Yılmaz (2022) calculated a composite risk index using energy intensity, import dependency, domestic production, and geopolitical risk indicators for the period 1980-2016 in Turkey. According to the findings, fossil fuel consumption and low domestic energy production cause Turkey's energy supply security problem.

4. Empirical Analysis

The literature on energy supply security is discussed in the previous section. As can be seen from the literature review, energy supply security indices are generally used in energy supply security calculations and forecasts. Since one of the most important causes of the energy supply security problem is energy external dependence (Birol, 2021, p.445), energy external dependence is at the center of energy supply security studies in addition to energy supply security indices (Erdal, 2015, p.154). Therefore, in this part of the study, an analysis was conducted in which the dependent variable is energy external dependence. ARDL cointegration and Toda-Yamamoto causality tests were applied in the analysis.

4.1. Data Set

In this study, Turkey's 34-year period between 1987-2020 is analyzed. 6 different variables are used. The first variable, energy dependence, which is also the dependent variable of the study, is compiled from Eurostat. All independent variables, except Gross Domestic Product (GDP), are determined by energy supply sources produced in Turkey. These energy sources are coal, natural gas, oil, and renewable energy. The data on coal and natural gas are compiled from the Coal and Energy Report of the Chamber of Mining Engineers (MMO). The author obtained coal data by summing hard coal and lignite. Other independent variables are compiled from OECD Data. The variables used in this model are shown below with the names used in the model.

Table 1: Basic information about the variables in the model

Dependent/Independent	Variable	Dataset	Measure
Dependent variable	Dependency	Eurostat	Net imports/gross available energy (%)
Independent variable (1)	GDP	OECD	Million US Dollars
Independent variable (2)	Coal	MMO	Tons of oil equivalent
Independent variable (3)	Naturalgas	MMO	Tons of oil equivalent
Independent variable (4)	Oil	OECD	Tons of oil equivalent
Independent variable (5)	Renewable	OECD	Tons of oil equivalent

The variables introduced above can be expressed as follows with the help of equation 1 below.

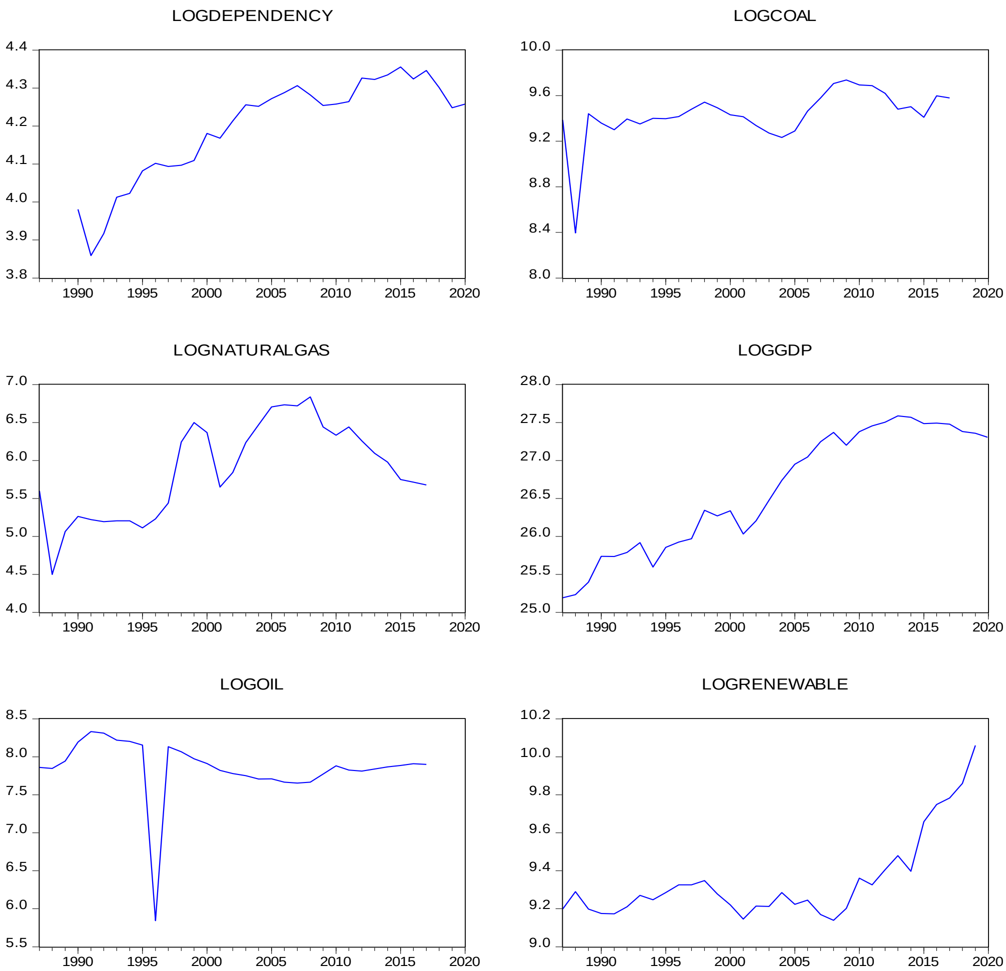
$$dependency_t = \alpha_0 + b_1*GDPt + b_2*coalt + b_3*naturalgas_t + b_4*oil_t + b_5*renewable_t + \mu_t \quad (1)$$

In addition, the logarithm of these variables in the model is taken for easier interpretation of the model. The logarithm of the model is shown below.

$lndependency_t = \alpha_0 + b_1*lnGDPt + b_2*lncoalt + b_3*lnnaturalgas_t + b_4*lnoil_t + b_5*lnrenewable_t + \mu_t$ (2)

Graphical representation of the variables in the model is given below. In the graphs, it can be said that the variables in the model may include a trend, so it is necessary to perform tests that include a trend when performing unit root tests.

Figure 1. Graphical Representation of Variables in the Model



4.2. Methodology and Empirical Findings

This section presents the tests conducted and the results obtained by the methodological sequence. In this context, this section includes unit root tests, ARDL bounds test, diagnostic tests, and the Toda-Yamamoto test.

4.2.1. Unit Root Tests

ADF (Augmented Dickey-Fuller) is one of the most widely used unit root tests in the literature. One of the basic assumptions of this test is that the error terms are independent and homogeneous (Eyüboğlu and Abdioğlu, 2019, p.237). There are 3 different ADF tests in equations 3, 4 and 5 below. The first equation has no constant term and no trend, the second equation has a constant term and no trend, and finally the third equation has both a constant term and a trend.

$$\Delta Y_t = \delta Y_{t-1} + \mu_t \quad (3)$$

$$\Delta Y_t = b_0 + \delta Y_{t-1} + \mu_t \quad (4)$$

$$\Delta Y_t = b_0 + b_1 t + \delta Y_{t-1} + \mu_t \quad (5)$$

In this test, the null hypothesis (h_0) is "the series contains unit root and is non-stationary" while the alternative hypothesis (h_1) is "the series does not contain unit root and is stationary". Then, the statistics obtained as a result of the ADF test are compared with the MacKinnon critical values at 1%, 5% and 10% significance levels to determine whether the series is stationary or not.

The KPSS unit root test developed by Kwiatkowski, Phillips, Schmidt and Shin in 1992 is also used together with the ADF test as a control. What distinguishes the KPSS unit root test from other tests is that the nonparametric estimator of the long-run variance of the residuals forms the basis of this test (Çağlayan and Saçakçı, 2006, p.124). The test equation can be shown as follows with the help of equation 6 below. In this equation, xt denotes the deterministic component.

$$Y_t = x_t'\delta + \mu_t \quad (6)$$

With equation 7, the residuals are added to the equation and the test is calculated. In this equation, t is the number of observations, S_t is the cumulative residual and f_0 is the spectrum estimator at zero frequency.

$$LM = T^{-2}\sum_{i=1}^{T} S_t^2 / f_0 \quad (7)$$

In the KPSS unit root test, unlike other unit root tests, $H_0: \rho < 1$ ve $H_1: \rho = 1$. In other words, in this test, while H_0 is that the series does not contain unit root and is stationary, the alternative hypothesis is H_1 that the series contains unit root and is non-stationary.

The results obtained by applying the unit root tests to the variables in the model are presented in the table below. In the first test, ADF (both in the constant and constant and trend application), H_0 is accepted, i.e. all of the series except lnoil contain unit root and are non-stationary at the level I(0). Therefore, differences were taken to stationarize the series. As a result of this process, the series became stationary at first difference I(1).

Tablo 2: ADF Unit Root Test

Variables	Constant		Constant and Trend	
	I(0)	I(1)	I(0)	I(1)
lndependency	0,4742	0,000	0,9121	0,000
lnGDP	0,4284	0,000	0,9027	0,000
lncoal	0,5590	0,000	0,0669	0,000
lnnaturalgas	0,1315	0,000	0,8173	0,000
lnoil	0,000	-	0,000	-
lnrenewable	0,9995	0,000	0,9981	0,000

The results of the second test, the KPPS unit root test, are presented below. As a result of this test, the dependent variable lndependency is stationary at I(1), while the dependent variables lnGDP, lncoal, innaturalgas and lnoil are stationary at I(0) or I(1) according to the 5% critical value. The last variable, lnrenewable, is stationary at I(1) at the 1% level both in the model with constant term and in the model with constant term and trend. As a common result of the two tests, the dependent variable is I(1) and the independent variables are I(0) and I(1) in both the model with constant term and the model with constant term and trend.

Table 3: KPSS Unit Root Test

ariables	Constant				Constant and Trend			
	I(0)		I(1)		I(0)		I(1)	
	KPSS Test Statistics	1% and 5% Critical Value	KPSS Test Statistics	1% and 5% Critical Value	KPSS Test Statistics	1% and 5% Critical Value	KPSS Test Statistics	1% and 5% Critical Value
lndependency	0,7466	0,4630	0,2417	0,4617	0,2056	0,1460	0,077	0,1460

ariables	Constant				Constant and Trend			
	I(0)		I(1)		I(0)		I(1)	
	KPSS Test Statistics	1% and 5% Critical Value	KPSS Test Statistics	1% and 5% Critical Value	KPSS Test Statistics	1% and 5% Critical Value	KPSS Test Statistics	1% and 5% Critical Value
lnGDP	0,9055	0,4630	0,2447	0,4630	0,1335	0,1460	-	-
lncoal	0,5038	0,4630	0,0626	0,4630	0,0653	0,1460	-	-
lnnaturalgas	0,5144	0,4630	0,1520	0,4630	0,1750	0,1460	0,1193	0,1460
lnoil	0,1562	0,4630	-	-	0,0831	0,1460	-	-
lnrenewable	0,5643	0,4630	0,4917	0,7390	0,1973	0,1460	0,1621	0,2160

4.2.2. ARDL[6] Bounds Test

The ARDL bounds test has some advantages over other cointegration tests used in the literature (Johansen cointegration, etc.). The ARDL bounds test can be applied regardless of whether the independent variables in this test are stationary at the level or at the first level. The ARDL bounds test is also considered to be a more reliable method than other tests for models with small sample sizes (as in this study) (Pamuk and Bektaş, 2014, 82). There is a 3-stage analysis in the ARDL test. The bounds test equation used in the first stage of the test and adapted to this study is shown in (8) below. In the model, α is the constant coefficient, Δ is the difference operator, μ is the error term and m is the lag length. In order to investigate the existence of cointegration relationship in this model, the F-statistic value is calculated and if the values obtained are above the upper values determined by Pesaran (2001), it is concluded that the model is cointegrated.

$$\Delta lndependency = a_0 + \sum_{i=0}^{m} a_{1i}\Delta lndependency_{t-i} + \sum_{i=0}^{m} a_{2i}\Delta lnGDP_{t-i} + \sum_{i=0}^{m} a_{3i}\Delta lncoal_{t-i} + \sum_{i=0}^{m} a_{4i}\Delta lnnaturalgas_{t-i} + \sum_{i=0}^{m} a_{5i}\Delta lnoil_{t-i} + \sum_{i=0}^{m} a_{6i}\Delta lnrenewable_{t-i} + a_7 lndependency_{t-1} + a_8 lnGDP_{t-1} + a_9 lncoal_{t-1} + a_{10} lnnaturalgas_{t-1} + a_{11} lnoil_{t-1} + a_{12} lnrenewable_{t-1} + \mu_t \quad (8)$$

[6] Autoregressive-Distributed Lag

After determining that and if there is a relationship between the variables in Model (8), the long-run relationship of the variables is investigated in the second stage of ARDL. Model (9) shows the equation with the long-run coefficients of the variables.

$$\Delta \text{lndependency} = a_0 + \sum_{i=0}^{m} a_{1i}\Delta \text{lndependency}_{t-i} + \sum_{i=0}^{m} a_{2i}\Delta \text{lnGDP}_{t-i} + \sum_{i=0}^{m} a_{3i}\Delta \text{lncoal}_{t-i} + \sum_{i=0}^{m} a_{4i}\Delta \text{lnnaturalgas}_{t-i} + \sum_{i=0}^{m} a_{5i}\Delta \text{lnoil}_{t-i} + \sum_{i=0}^{m} a_{6i}\Delta \text{lnrenewable}_{t-i} + \mu_t \quad (9)$$

Finally, short-run relationships are analyzed. In this context, the error correction term (EC) is added to the equation. The EC term below stands for the error term.

$$\Delta \text{lndependency} = a_0 + \sum_{i=0}^{m} a_{1i}\Delta \text{lndependency}_{t-i} + \sum_{i=0}^{m} a_{2i}\Delta \text{lnGDP}_{t-i} + \sum_{i=0}^{m} a_{3i}\Delta \text{lncoal}_{t-i} + \sum_{i=0}^{m} a_{4i}\Delta \text{lnnaturalgas}_{t-i} + \sum_{i=0}^{m} a_{5i}\Delta \text{lnoil}_{t-i} + \sum_{i=0}^{m} a_{6i}\Delta \text{lnrenewable}_{t-i} + \beta EC_{t-1} + \mu_t \quad (10)$$

As will be recalled from the first part of the analysis, the unit root tests revealed that the dependent variable of the series is I(1) and the independent variables are either I(0) or I(1). Therefore, it would be appropriate to continue the analysis with the ARDL bounds test. In the selection of the model, the Akaike Information criterion was used and it was found that it was appropriate to use the ARDL (2,2,2,2,2,2) model among the best 20 models. This shows that the variables are analyzed with a maximum lag length of 2.

In the first stage of the ARDL bounds test, the F-statistic value was determined as 38.80. As can be seen from the table below, the F-statistic value is greater than the 1%, 5% and 10% critical values. This proves the existence of a cointegration relationship. This indicates that there is a relationship between external energy dependence and domestic energy supply.

Table 4: ARDL Critical Values

Percentage (%)	**Value**	
	I(0)	I(1)
10	2,75	3,79
5	3,12	4,25
1	3,93	5,23

In the second stage of the ARDL Test, the existence of a long-run cointegration relationship is investigated. The r-square (0.999), adjusted r-square (0.9965) and F-statistic probability values (0.000) of the model indicate that the model as a whole is statically meaningful. When the variables of the model are analyzed, it is seen that lncoal, lnoil and lnrenewable have a value below the 1% critical value (the probability value of all 3 variables is

0.000) and are significant. According to the results obtained, in the long run, a 1-unit increase in domestic coal supply reduces energy dependence by 17.3%, a 1-unit increase in domestic oil production reduces energy dependence by 5%, and finally, a 1-unit increase in renewable energy supply reduces energy dependence by 18.4%. Since the other variables used in the study, lnGDP and lnnaturalgas, are greater than the critical values of 1%, 5% and 10%, no comments can be made on these variables.

Table 5: ARDL Model: Long Run

Variables	Coefficients	t-statistics	Probability
lnGDP	-0,0147	-1,0345	0,3353
lncoal	-0,1734	-8,7185	0,000
lnnaturalgas	0,012	1,8510	0,1066
lnoil	-0,052	-7,3750	0,000
lnrenewable	-0,1847	-7,1523	0,000

In the ARDL model, the EC model is used to examine the short-run relationship. The data for this model are given in the table below. The negative coefficient of the model (-1.3591) indicates that the model is valid. In addition, the fact that the probability value is smaller than the critical values of 1%, 5% and 10% allows the interpretation that the result obtained is significant. According to the error correction test, it is concluded that there is a cointegration relationship between the variables in the model in the short run.

Table 6: ARDL Model: Short Run

Variables	Coefficients	t-statistics	Probability
CoinEq(-1)	-1,3591	-19,9784	0,0000

4.2.3. Diagnostic Tests

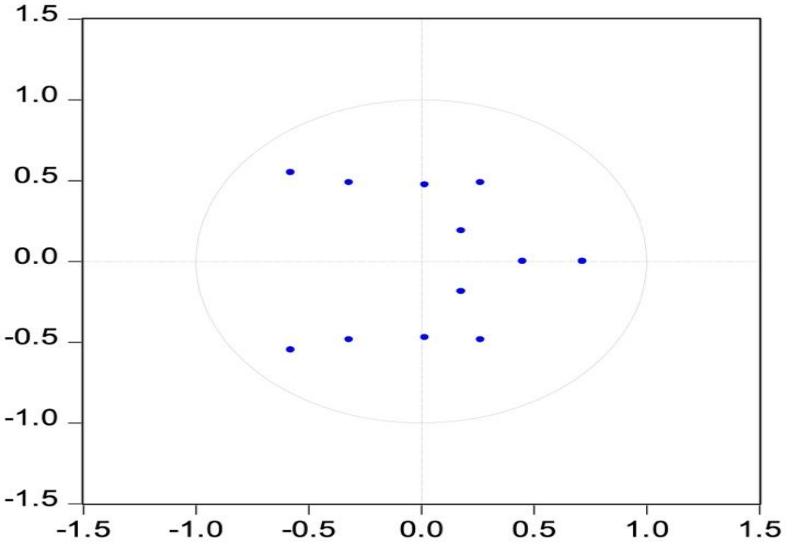
In this study, various diagnostic tests were also conducted to test the validity of the ARDL bounds test. In the first of these tests, the normality test, the Jarque-Bera coefficient is 0.2195 and the probability value is 0.8960. The value obtained is higher than the 5% limit value. This can be interpreted that the series in the model are normally distributed. The second test, Breusch-Godfrey Serial Correlation LM test, has an F-probability value of 0.5933, a probability value of 0.5872 and a chi-square probability value of 0.082. The results indicate that the series are uncorrelated at the 5% significance level. The third test, Breusch-Pagan-Godfrey heteroscedasticity test, is performed to determine whether there is a problem of changing variance in the model. As a result of this test, the F-Likelihood Value is 0.3455 and the Chi-square value is 0.8350 and it is seen that there is no problem of changing variance. The next test, the Ramsey RESET test, is used to investigate the presence of a model setup error. While the F-statistic value of this test is 0.0397, the probability value is 0.8485 and it is understood that there is no error in the model setup. The results of the diagnostic tests are given below.

Table 7: Summary of Diagnostic Tests

Test	F-Statistic	R^2	Probability	Ki-Square-Probability
Jarque-Bera Test			0,2195 (0,8960)	
Breusch-Godfrey Serial Correlation LM Test	0,5933	4,9873	0,5872	0,082
Breusch-Pagan-Godfrey Heteroscedasticity Test	0,3455	12,2327	0,9673	0,8350
Ramsey RESET Test	0,0397		0,8485	

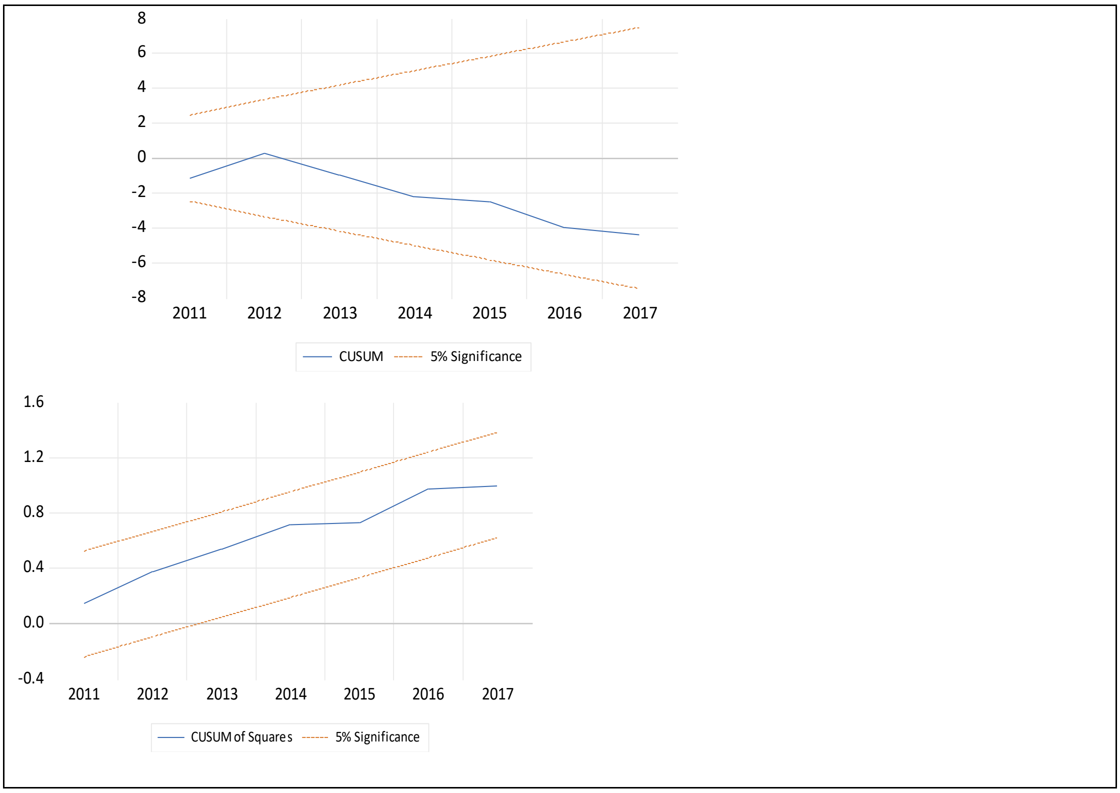
The other test is inverse roots of the AR characteristic polynomial test. This test is used to investigate whether the variables satisfy the stability condition. This approach increases the reliability of the results obtained with unit root tests, thus making the analysis more robust. As a result of the test, all dots in Figure 2 were within the unit root circle. Thus, it is understood that the model has no stability problem.

Figure 2: Inverse Roots of AR Characteristic Polynomial



The last of the diagnostic tests is the CUSUM tests. The results obtained as a result of these tests, called CUSUM and CUSUM of Square tests, are compared with the values obtained at the 5% significance level. Thus, it is understood whether there is any structural break problem in the model. The results of the tests performed according to this model are shown in the figure 3 below. As can be seen from the figure, CUSUM and CUSUM of Square test statistics are within the 5% significance level. This leads to the conclusion that the coefficients in the model are stable and no structural break problem is detected.

Figure 3: Cusum and Cusum^2 Test Statistics Result



4.2.4. Toda-Yamamoto Causality Test

Finally, the Toda-Yamamoto causality test is performed and the study is concluded. In the Toda-Yamamoto test, the test starts by determining $k+d_{max}$. D_{max} refers to the maximum degree of integration of variables and is determined by unit root tests. Within the scope of this study, d_{max} is set as 1 since the findings obtained from the unit root tests determine stationarity at I(1) at most. The k in the equation denotes the lag length. As a result of the lag length test, k is determined as 2 and it is understood that the appropriate lag length for the Toda-Yamamoto test is 3. Then, the Wald test was performed, and the causality relationship was determined by comparing the table value with k degrees of freedom.

Table 9: k+d_{max} for Toda-Yamamoto

k	d_{max}	Lag Length (k+d_{max})
2	1	3

The causality results of the variables are shown below. According to the results obtained, a two-way Granger causality relationship was found between coal and oil supply and energy dependence at a 5% level of significance. In addition, at the 10% level of significance, there is a two-way Granger causality relationship between GDP and energy dependence. There is a one-way relationship between renewable energy and energy dependence and energy dependence is the Granger cause of renewable energy at the 5% significance level. There is no relationship between the last variable, natural gas, and energy dependence.

Table 10: Toda-Yamamoto Test Statistics

Causality	**Chi-Square Statistic**	**Freedom D.**	**Probability**
lncoal→lndependency	32,92133	3	0,0334
lnGDP→ lndependency	10,26584	3	0,0164
lnrenewable→ lndependency	5,066366	3	0,1670
lnoil→ lndependency	9,387837	3	0,0246
lnnaturalgas→lndependency	5,240536	3	0,1550
lndependency→ lncoal	9,643669	3	0,0218
lndependency→ lnGDP	7,739543	3	0,0517
lndependency→ lnrenewable	29,05241	3	0,2183
lndependency→ lnoil	51,77244	3	0,0000

lndependency→ lnnaturalgas	3,07535 0	3	0,3801

CONCLUSION AND POLICY SUGGESTIONS

Energy supply security has become a central issue in the energy policies of many countries due to developments in recent years. Turkey has also started to work on energy supply security due to the economic, social, and environmental risks it faces in the field of energy. In this context, policies such as exploration and production of oil and natural gas, exploitation of mines such as hard coal and lignite, the establishment of nuclear power plants, increasing the share of renewable energy in primary energy supply, reducing energy intensity, diversification of the source of imported natural gas and transportation of natural gas to Europe via Turkey are being developed.

As reflected in the IEA's reports, oil and natural gas exploration and production, which are among the methods listed above, have become Turkey's political priority in energy. As is known, the transition to renewable energy has taken many years and has not yet reached the desired technological level in many areas, especially in electricity generation. Therefore, oil and natural gas exploration and production can be beneficial in the short term if the costs of drilling, exploration, production, and operation are low compared to imported oil and natural gas. If oil and natural gas exploration and production are considered a long-term strategy, it will cause serious negative environmental impacts and reinforce Turkey's dependence on fossil fuels. Therefore, Turkey's political priority in the energy sector should be to increase renewable energy both to reduce external dependence and to reduce fossil fuel dependence. In the last 10 years, Turkey has spent an average of 45 billion dollars annually on energy imports. Even 10% of this resource annually would be sufficient to create renewable energy infrastructure, ensure energy efficiency, encourage the private sector to invest more in the renewable energy sector, and support green R&D and technologies. Thus, Turkey can gradually transition to renewable energy.

Coal, one of the other energy sources included in the study, is an energy source that should not be included in Turkey's energy mix due to environmental pollution and the health problems it causes in humans. In addition, the continued coal production and use will cause Turkey to face various environmental sanctions in the coming years. Whether nuclear energy is a clean energy source is controversial, while its ability to reduce foreign dependence on energy is only on the surface. Because nuclear power generation is carried out under the management of foreign companies with the raw materials, technology, and engineering provided by these companies.

Finally, the findings from the tests conducted in this study show that there is a cointegration relationship between energy external dependence, which is the most important element of energy supply security, and domestic primary energy supply both in the short run and in the long run between 1987 and 2020. When the degree of the effect of variables on energy external dependence is analyzed, it is observed that renewable energy supply reduces energy external dependence the most in the long run, while coal and oil supply also contribute to the reduction of energy external dependence. The other variables included in the model, namely GDP and natural gas supply, have not yielded any findings. The Toda-Yamamoto causality test conducted in the study is important in observing the direction of the relationship between the dependent and independent variables. According to the results obtained from this test, there is a unidirectional relationship between energy dependence and renewable energy supply and energy dependence is the Granger cause of renewable energy supply. There is a 2-way Granger causality relationship between the other variables, GDP (10% significance level), coal and oil production (5% significance level), and energy dependence. The results obtained are important in terms of understanding the policies implemented for Turkey's energy supply security. Oil production does not make a sufficient contribution to reducing external energy dependence. Therefore, it is aimed to reduce external dependence on energy by increasing oil (and natural gas) production. However, even if this reduces external energy dependence, it carries the risk of increasing fossil fuel dependence. This is environmentally unsustainable and will result in resources that could be used for renewable energy being used in the fossil fuel industry. This will make Turkey's green transition more difficult. It would also mean neglecting sustainability, which is one of the main components of energy supply security. A review of the literature also shows the importance of renewable energy in achieving energy independence. Fossil fuels, on the other hand, are an obstacle to renewable energy and thus to localization in energy.

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