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A NEW ENERGY SUPPLY RISK INDEX AND ITS NEXUS WITH RENEWABLE ENERGY CONSUMPTION IN TÜRKİYE

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ABSTRACT

Energy security is defined as the uninterrupted and affordable availability of energy and is considered a vital component of economic, social, and environmental development. However, the significant share of fossil fuels in global energy consumption exposes societies to supply disruptions and economic risks. To mitigate these risks, diversification of energy sources and supply routes is essential. While various indices have been developed in the literature to measure energy supply security, these indices often fall short of comprehensively assessing energy supply risks. This study introduces a new energy supply security index aimed at overcoming these limitations by incorporating domestic consumption and import dependency into the evaluation. The proposed Energy Supply Risk Index (ESRI) is developed using adjusted Herfindahl-Hirschman Index (HHI) that accounts for energy import intensity and weights the share of each energy source in total consumption. The study demonstrates the application of ESRI through the case of Türkiye and analyzes the relationship between renewable and non-renewable energy consumption using the Nonlinear Autoregressive Distributed Lag (NARDL) approach. The findings reveal the complex nature of risks associated with different levels of energy dependency and underscore the importance of transitioning to diversified and sustainable energy systems. By offering a more realistic measurement of energy supply risks, the ESRI provides policymakers with a robust tool for energy planning and risk management.

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YENİ BİR ENERJİ ARZ RİSKİ ENDEKSİ VE TÜRKİYE'DE YENİLENEBİLİR ENERJİ TÜKETİMİ İLE İLİŞKİSİ

MAKALE BİLGİSİ

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ÖZ

Enerji güvenliği, enerjinin kesintisiz ve uygun maliyetle erişilebilirliği olarak tanımlanmakta ve ekonomik, sosyal ve çevresel kalkınmanın temel bir unsuru olarak kabul edilmektedir. Bununla birlikte, küresel enerji tüketiminde fosil yakıtların yüksek paya sahip olması, arz kesintileri ve ekonomik riskler açısından toplumları savunmasız hale getirmektedir. Bu risklerin azaltılması için enerji kaynaklarının ve tedarik yollarının çeşitlendirilmesi hayati öneme sahiptir. Literatürde enerji arz güvenliğini ölçmek için çeşitli endeksler geliştirilmiş olsa da bu endekslerin enerji arz risklerini kapsamlı bir şekilde değerlendirme kapasitesi sınırlıdır. Bu çalışma, enerji arz güvenliği değerlendirmesinde mevcut kısıtlamaları aşmayı hedefleyen ve iç tüketim ile ithalat bağımlılığını da dikkate alan yeni bir enerji arz güvenliği endeksi geliştirmektedir. Enerji ithalat yoğunluğunu göz önünde bulundurarak düzeltilmiş Herfindahl-Hirschman Endeksi (HHI) ile her bir enerji kaynağının toplam tüketim içindeki payını ağırlıklandıran Enerji Arz Riski Endeksi (ESRI) önerilmektedir. Türkiye örneği üzerinden gerçekleştirilen bu çalışmada, ESRI'nin uygulanabilirliği gösterilmiş ve yenilenebilir ile yenilenemeyen enerji kaynaklarının tüketimi arasındaki ilişki, Doğrusal Olmayan Gecikmeli Dağıtılmış Otokoregresyon (NARDL) yöntemi ile analiz edilmiştir. Elde edilen bulgular, enerji bağımlılığı ile ilişkili risklerin karmaşık yapısını ortaya koyarak çeşitlendirilmiş ve sürdürülebilir enerji sistemlerine geçişin gerekliliğini vurgulamaktadır. ESRI, enerji arz risklerini daha gerçekçi bir şekilde ölçme imkânı sunarak, politika yapıcılar için enerji planlaması ve risk yönetimi süreçlerinde güçlü bir araç sağlamaktadır.

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1. INTRODUCTION

Energy is essential for all aspects of society, from the production and distribution of goods to daily life. The growth of technology in the 20th century has led to a significant increase in energy consumption. The fossil-based resources like oil, natural gas, and coal plays a significant role in meeting the world's primary energy demand. As these resources are not evenly distributed, countries that have a surplus of fossil fuel trade with those that lack adequate resources. However, relying on a single source or a few suppliers for energy can be a risky proposition for importing countries, as any supply disruption in exporting countries can lead to significant economic impacts. To mitigate this risk, net energy importers are shifting to alternative energy sources that can replace fossil fuels. Despite this shift, fossil fuels still have a significant share in the world's energy consumption. This exposes societies to energy bottlenecks. Therefore, ensuring a steady, affordable supply of energy has become a vital issue for economic, social, and environmental development. The International Energy Agency (IEA) defines energy supply security as the "uninterrupted availability of energy sources at an affordable price". In other words, it is essential to meet the increasing energy needs in a sustainable, affordable, and uninterrupted manner. Therefore, it is crucial to diversify the sources and routes of energy to minimize any risks that might arise from using fossil fuels.

The energy supply problem first emerged in the 1970s with the oil crisis, and it has since re-emerged due to the Covid-19 pandemic and the Russia-Ukraine crisis. During these crises, the rapid rise in energy prices had a detrimental effect on the economies of developed and developing countries alike. Thus, countries are attempting to diversify their energy sources to reduce reliance on a single supplier and to mitigate any supply problems. The issue of whether this diversification is sufficient, that is, whether countries will experience energy shortages in case of any problem, has brought up the research of measuring energy supply security. To this end, various studies have been conducted (Birol, 2021; Blyth and Lefevre, 2004; Cabalu, 2010; Costantini et al., 2007; Gupta, 2008; Jansen et al., 2004; Kendell, 1998; Kruyt et al., 2009; Neumann, 2003; Şimşek, 2012; Arslan ve Demir, 2024). In this study, we will first present an energy supply risk index (ESRI) that measures the energy supply risk more sensitively and realistically than the examples in the literature. Additionally, to demonstrate the applicability of the ESRI, we will use NARDL analysis to examine its relationship with both renewable and non-renewable energy consumption in Türkiye.

2. MARKET CONCENTRATION INDEX (HHI INDEX)

In the case of the structure of the market (perfect competition, monopolistic competition, oligopoly, or monopoly) is unknown, it can lead to unfair competition and hinder the economy's healthy functioning. To avoid this, diversification or concentration indices are used. One widely used index is the Herfindahl-Hirschman index (HHI). This index measures the market concentration ratio by highlighting the market shares of the companies in the market. It was simultaneously developed by C. Herfindahl and Albert O. Hirschman. The HHI index is

calculated by squaring the market shares of firms in a market and then summing the resulting numbers. The equation for HHI index is as follows (WEC, 2008):

$$HHI = \sum_{i=1}^n p_i^2 = p_1^2 + p_2^2 + \dots + p_n^2 \quad (1)$$

Here, p_i 's indicates the i^{th} firm's market share for $i = 1, 2, \dots, n$. So,

$$p_i = \frac{\text{size of the } i^{th} \text{ firm}}{\text{size of the market}}$$

If a single firm owns the entire market, the HHI index value is 1, indicating a monopoly where there is no competition. As concentration decreases and competition increases, the HHI value approaches 0. When the value is close enough to zero, there are many firms with very low market shares in the market and perfect competition market conditions are approached. Thus, this index takes value in (0,1] interval, where lower values indicate a positive situation in terms of market concentration, and higher values indicate a negative situation.

3. ENERGY SUPPLY RISK INDEX (ESRI)

Ensuring country and/or route diversity in energy source imports is crucial in minimizing the negative effects that may arise in the energy supply of importing countries. To determine the level of risk that may arise, various diversification or concentration indices are widely used in literature. One such index is the HHI, which measures the market concentration, as mentioned above. The HHI index based on market concentration aligns with the concept of energy supply security, which emphasizes the importance of diversifying the countries from which energy is imported. To measure the diversity of countries in energy supply, an adapted version of the HHI index is used in the energy market. This index calculates the level of diversification by summing the squares of the shares of the countries from which an energy source is imported in the total import of that energy source.

$$HHI_i = \sum_{j=1}^n s_j^2 = s_1^2 + s_2^2 + \dots + s_n^2 \quad (2)$$

$$0 < HHI_i \leq 1$$

Here, i is the imported energy source (oil, natural gas, coal, etc.), j is the country from which the energy source is imported, s_j 's indicate the j^{th} country's share in the total import amount of respected energy source. So,

$$s_j = \frac{\text{amount of respected energy source imported from } j^{th} \text{ country}}{\text{total import amount of respected energy source}}$$

Similar to the market concentration index, importing an energy source from a single country or a small number of countries poses a risk to energy supply security. For example, if

all energy imports come from only one country, the HHI index value is equal to 1, indicating the highest level of risk. However, as the number of countries from which energy is imported increases and concentration decreases, the HHI value approaches 0, and the energy supply risk decreases accordingly.

The main premise of this index is that importing energy sources from several countries will reduce the risk. Thus, the effects of supply disruptions in exporting countries are expected to be low on importing countries. In this respect, although HHI is a useful index to measure energy supply risk by taking into account the country's concentration in the import of an energy source, it may lead to wrong decisions in some cases. These cases can be summarized as follows:

- (1) *Importing the majority of an energy source, which has a low share in domestic consumption, from a single country:* The HHI value will be maximum if an entire energy resource, which has a very low share (e.g., 1%) in the country's energy consumption, is imported from a single country. However, it is important to note that an energy source with low domestic consumption has a low impact on the overall energy supply risk.
- (2) *Importing an energy source, the majority of which is supplied by domestic sources, from a single country:* Although a large part of the energy source (e.g., 99%), which has a high share in the country's energy consumption, is met domestically, the HHI value will be maximum if the rest (1%) is imported from a single country. However, the energy supply risk is low due to the high domestic supply.

The first problem that prevents the use of the HHI index in measuring the energy supply risk is related to low domestic consumption rates, while the second is related to low import rates. Therefore, an index that can present reliable results should consider both the domestic consumption and import rates of the energy source. With these requirements in mind, we have developed a new energy supply risk index based on the HHI index, which aims to measure energy supply risk in a more realistic way. This index is composed of five stages.

First Stage:

As mentioned above, the new index should take into account the domestic consumption rate of the energy source. The equation to be used to calculate the domestic consumption rate is as follows:

$$SEC_i = \frac{GIC_i}{GIC} \quad (3)$$

$$0 \leq SEC_i \leq 1$$

Here, i indicates the energy source used (oil, natural gas, coal, etc.), GIC (Gross inland consumption) represents the total domestic energy consumption. Therefore, the SEC gives the share of the selected energy source in total domestic consumption.

Second Stage:

Now, we calculate the import rate of the energy source by using the equation (4).

$$EID_i = \frac{M_i - X_i}{GIC_i} \quad (4)$$

$$0 \leq EID_i \leq 1$$

Here, i is the energy source used (oil, natural gas, coal, etc.), M is the total import amount (value) of the energy source, X is the total export amount (value) of the energy source, GIC is the total domestic energy consumption. Therefore, the EID shows the share of net imports, which is the difference between the import and export, of the energy source in domestic consumption, that is, the import dependency of the energy source.

Third Stage:

We will calculate the correction coefficient term (CCT) to be added to the HHI index by multiplying the SEC and EID given in equation (3) and (4).

$$CCT_i = SEC_i \times EID_i$$

$$CCT_i = \frac{GIC_i}{GIC} \times \frac{M_i - X_i}{GIC_i} = \frac{M_i - X_i}{GIC} \quad (5)$$

$$0 \leq CCT_i \leq 1$$

Here, i indicates the energy source used (oil, natural gas, coal, etc.).

According to the generally accepted approach, import dependency is the ratio of net imports (imports minus exports) of an energy source to its gross available amount. The CCT calculated here takes into account the share of the imported energy in the total domestic energy consumption. We will use the CCT for weighing to eliminate the above-mentioned problems that arise when the HHI index is used. Thus, CCT will help us to calculate a more realistic index value in terms of the energy market.

Fourth Stage:

By multiplying the CCT value of each energy source with the HHI index of respected source, the corrected HHI index for the energy source (EHHI) is calculated.

$$EHHI_i = CCT_i \times HHI_i \quad (6)$$

$$0 \leq EHHI_i \leq 1$$

Here, i indicates the energy source used (oil, natural gas, coal, etc.).

In the worst-case scenario, if the energy need is met from a single energy source that is all imported and at the same time this import is made from a single country, the index value

will be 1. Otherwise, if the energy source is not used or all of the used amount is met by domestic resources, the index value will be 0.

Fifth Stage:

At the final stage, to create the ESRI, we will sum the EHHI index values calculated separately for all imported energy sources.

$$ESRI = \sum_{i=1}^n EHHI_i \quad (7)$$

$$0 \leq ESRI \leq 1$$

Here, i indicates the energy source used (oil, natural gas, coal, etc.).

The ESRI index takes values in $[0, 1]$ interval. While lower values indicate that the risk is low, the ESRI value will be high in case of an increase in risk. Let's explain these two extreme cases and a possible case with the help of three examples:

- *Example 1 (Maximum risk):* It is clear that if country A's energy needs are met from a single source and this source is supplied only from country B, the EHHI value of this source will be 1 and the EHHI value of other sources will be 0 since the other sources are not used. Therefore, the ESRI value, which is the sum of the EHHI values, will be 1. The energy supply risk of country A is at the maximum level. In other words, if there is a supply problem in country B (or a problem with country B), the energy supply of country A will be endangered.
- *Example 2 (No risk):* It is clear that if country A's energy needs are met from local sources, EHHI values for all resources will be 0. Hence, the ESRI value, which is the sum of the EHHI values, will be 0. The energy supply risk of country A is at a minimum level. In other words, since the country meets its energy needs from its own resources, there will be no energy supply problem.
- *Example 3 (possible low-risk):* If some of the resources that country A meets its energy needs are imported and the supply of imported resources is obtained from many countries, the HHI values of the imported resources and therefore the EHHI values will be low. Therefore, the ESRI value, which is the sum of the EHHI values, will be relatively low. In other words, although some of the energy sources are imported, the energy supply risk will not be high since the source country is diversified.

The HHI index, which has been adapted to the energy market, considers the country's diversification in importing an energy source. According to this index, the energy supply risk decreases as it approaches 0 and increases as it approaches 1. The ESRI index, which is based on the HHI index, takes into account not only the domestic consumption rates but also the import rates of energy sources. Thus, the values of the ESRI index are determined by the share of various energy sources in a country's total domestic energy consumption and the proportion

of imports in the consumption of these sources. As seen in the examples above, the ESRI index, like the HHI index, indicates that the risk decreases when it has a low value and increases when it has a higher value. Since the ESRI index eliminates the problems of the HHI index, it provides a more sensitive and realistic measurement of energy supply risk.

4. ECONOMETRIC APPLICATION

In this part of the study, we will conduct an econometric analysis to check the effectiveness of the energy supply risk index. To this end, annual data for the period 1990–2021 obtained from the Eurostat (Statistical Office of the European Communities) database is used. The general form of the model used in econometric analysis is as follows:

$$ESRI_t = f\left(\frac{RE}{NRE}\right)_t \quad (8)$$

Here, ESRI is the aforementioned energy supply risk index, RE is renewable energy usage and NRE is non-renewable energy usage. We have included the ESRI and RE/NRE ratio in the analysis by multiplying it by 100 in order to be able to comment more comfortably while interpreting the analysis results. Therefore, the ESRI variable we used in the analysis takes values in $[0, 100]$ interval. It is worth noting that this range will be considered in evaluating the analysis results. Due to the limited time period used in the analysis, no additional explanatory variables were included. The graph representing the variables used is presented below.

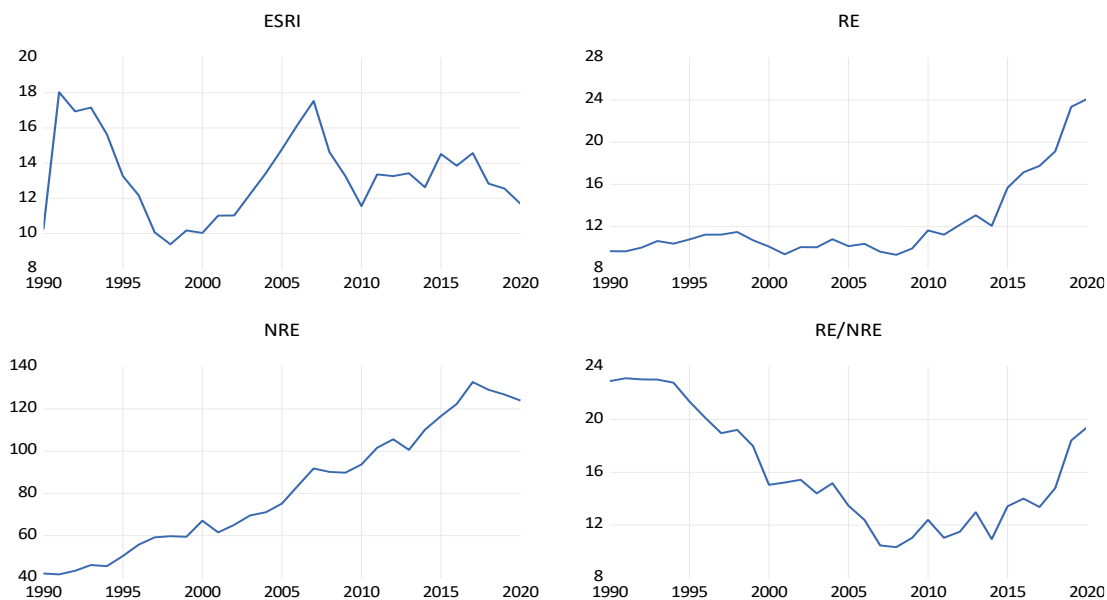


Figure 1. Graph of the variables

The linear model to be used in the analysis is as follows:

$$ESRI_t = C_0 + \beta_1 \left(\frac{RE}{NRE} \right)_t + \mu_t \quad (9)$$

Here, β_1 indicates the variable coefficient showing the long-term elasticity, C_0 is the constant, t is the time, and μ is the error term.

4.1. Stationarity Analysis

Econometric tests are particularly sensitive to the stationarity of the time series used, and failure to assess the stationarity levels may lead to the issue of spurious regression, where a relationship is falsely identified (Atmaca and Karadaş, 2020). Therefore, it is essential to select the appropriate test based on the stationarity properties of the series. In the context of the NARDL test, which is used to investigate asymmetric relationships, the dependent variable must be $I(1)$, while the other variables should either be $I(0)$ or $I(1)$, but not $I(2)$. To determine whether the time series are stationary, several unit root tests are available, including the ADF (Augmented Dickey-Fuller) test, the PP (Phillips-Perron) test, the DF (Dickey-Fuller) test, and the KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test. Among these, the ADF test is the most widely used and yields the most reliable results. Consequently, we employed the ADF test in this study, and the results are shown in Table 1.

Table 1. ADF unit root test results

Variables	Constant		Constant, Linear trend		None	
	t-Statistic	Prob.*	t-Statistic	Prob.*	t-Statistic	Prob.*
ESRI	-2.591035	0.1075	-2.836743	0.1978	-0.612170	0.4427
D(ESRI)	-2.897026**	0.0588	-7.386560	0.0000*	-2.937686	0.0049
RE/NRE	-1.470145	0.5347	1.575043	1.0000	-0.813413	0.3552
D(RE/NRE)	-4.514809*	0.0012	-4.434239	0.0078*	-4.567662	0.0000

Note: * and ** indicate the significance at level 1% and 5%, respectively.

As illustrated in Table 1, the results of the ADF unit root test indicate that all variables are integrated at the first order, or $I(1)$. This allows for the examination of the long-term relationship between the series using the NARDL approach.

4.2. Non-Linear Long-Term Relation

As previously discussed, cointegration tests in literature come with certain assumptions about the stationarity of variables. Standard OLS (Ordinary Least Squares) assumes that all variables in the dataset are $I(0)$, while the Engle and Granger (1987) and Johansen (1991) cointegration tests assume that the variables are $I(1)$. This becomes problematic for studies involving variables that are integrated at different orders. To overcome this challenge, Pesaran et al. (2001) introduced the ARDL model. The linear form of the ARDL model used in our analysis is as follows:

$$\Delta ESRI_t = \alpha_0 + \sum_{j=1}^n \alpha_{1j} \Delta ESRI_{t-j} + \sum_{j=0}^n \alpha_{2j} \Delta \frac{RE}{NRE}_{t-j} + \alpha_3 ESRI_{t-1} + \alpha_4 \frac{RE}{NRE}_{t-1} + u_t \quad (10)$$

The ARDL model consists of two stages. The first stage involves estimating equation (10) using standard OLS. In the second stage, the existence of cointegration between the variables is assessed by calculating the F-statistics based on the boundary test developed by Pesaran et al. (2001). The null hypothesis of the F-statistic states that “there is no cointegration between the variables” (i.e., $\alpha_3 = \alpha_4 = 0$), while the alternative hypothesis posits that “cointegration exists between the variables” (i.e., $\alpha_3 \neq \alpha_4 \neq 0$) (Nusair, 2017). It is important to note that the ARDL test results assume a symmetrical relationship between the variables, meaning it cannot capture any asymmetry. To address this limitation, Shin et al. (2014) introduced the non-linear ARDL (NARDL) approach, which allows for the examination of asymmetric relationships. In the NARDL model, the independent variables from equation (10) are separated into two distinct series to capture both positive and negative changes (Qamruzzaman and Jianguo, 2018).

$$\begin{aligned} X_t^+ &= \sum_{l=1}^t X_l^+ = \sum_{l=1}^t \text{MAX}(\Delta X_l, 0) \\ X_t^- &= \sum_{l=1}^t X_l^- = \sum_{l=1}^t \text{MIN}(\Delta X_l, 0) \end{aligned} \quad (11)$$

Here, X^+ and X^- represent the positive and negative variations of the variable X , respectively. Using these two series, we can write the non-linear form of the ARDL model as follows:

$$\begin{aligned} \Delta ESRI_t &= \beta_0 + \sum_{j=1}^n \beta_{1j} \Delta ESRI_{t-j} + \sum_{j=0}^n \beta_{2j} \Delta \left(\frac{RE}{NRE}\right)_{t-j}^+ + \sum_{j=0}^n \beta_{3j} \Delta \left(\frac{RE}{NRE}\right)_{t-j}^- + \gamma_0 ESRI_{t-1} \\ &\quad + \gamma_1^+ \left(\frac{RE}{NRE}\right)_{t-j}^+ + \gamma_1^- \left(\frac{RE}{NRE}\right)_{t-j}^- + u_t \end{aligned} \quad (12)$$

Here, β_i 's represent short-run elasticities, γ_i 's denote long-term elasticities, and n refers to the appropriate lag length (Qamruzzaman and Jianguo, 2018). According to Shin et al. (2014), the existence of a long-term relationship between the variables can be confirmed by comparing the F-statistics from the Wald test, as proposed by Pesaran et al. (2001), with the critical values. The null hypothesis of the Wald test is that “there is no long-term relationship between the variables” (i.e., $\gamma_0 = \gamma_1^+ = \gamma_1^- = 0$) (Shin et al., 2014).

As with the linear ARDL model, the boundary test for the NARDL model follows a similar procedure. The null hypothesis cannot be rejected if the F-statistic is lower than the lower bound, and no definitive conclusion can be drawn if the F-statistic falls between the two bounds. However, if the F-statistic exceeds the upper bound, the null hypothesis is rejected at

the chosen significance level. The null hypothesis for the F-statistic states that “there is no long-term relationship between the variables”, expressed as $H_0: \beta_i = 0, i = 1,2,3$. The results of the boundary test are provided in Table 2.

Table 2. NARDL Boundary test results

F-statistic	Degree of freedom
8.245696*	2
Critical value bounds at significance level 1%	
I(0)	I(1)
4.13	5

Note: *, indicates the significance at level 1%

As shown in Table 2, the F-statistic value of 8.24 exceeds the upper bound of the 1% significance level, which is 5. Consequently, the null hypothesis is rejected at the 1% significance level, indicating the existence of a long-term relationship between the series.

General linear regression models, including ARDL and NARDL tests, assume the absence of autocorrelation, meaning there is no relationship between the error terms. If autocorrelation is present, the model’s effectiveness is compromised. Autocorrelation can occur for various reasons, such as omitting key explanatory variables, incorrect selection of the model’s mathematical form, measurement errors in the dependent variable, data processing mistakes, or improper specification of the error term. To detect autocorrelation between the error terms, the serial correlation LM test is applied. The null hypothesis of the test is that “there is no autocorrelation between the series”. Rejecting this hypothesis confirms that the model is functioning effectively.

Another key assumption of these models is that the error terms exhibit constant variance, with zero covariance between them. If the variance of the error terms is not constant, the t and F statistics can yield biased results, making the test outcomes unreliable. To assess whether the variance is constant and the covariance between the error terms is zero, the Breusch-Pagan-Godfrey (BPG) heteroskedasticity test is applied. The null hypothesis of the BPG test must not be rejected to ensure the model does not suffer from heteroskedasticity. Based on this understanding, the results of the NARDL (3, 4, 1) test, the serial correlation LM test, and the BPG heteroskedasticity test are presented in the Table 3.

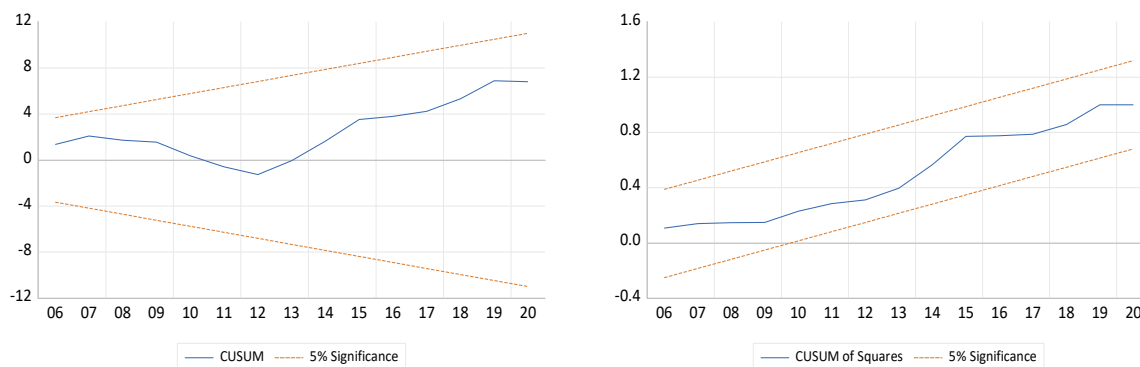
Table 3. The results of NARDL (3, 4, 1) test

Dependent variable: ESRI				
Variable	Coefficient	Std. error	t-Statistic	Probability
ECT	-0.359346	0.057119	-6.291212	0.0000
Long run form				
Variable	Coefficient	Std. error	t-Statistic	Probability
RE/NRE+	-2.087608*	0.992015	-2.104412	0.0526
RE/NRE-	-0.140948	0.182209	-0.773552	0.4512
C	9.906360	1.847438	5.362215	0.0001
$R^2 = 0.876656 \bar{R}^2 = 0.794426 F = 10.66107[0.000039]$				
$\chi^2_{BG} = 0.064883[0.9375]$				
$\chi^2_{BPG} = 1.872632[0.1319]$				

Note: *, indicates the significance at level 10%

As shown in the table, the error correction term (ECT) is statistically significant, with a coefficient of -0.36, which lies between -1 and 0. This indicates the presence of a long-term relationship within the model. In the event of a deviation from long-term equilibrium, the model is expected to return to equilibrium within approximately three periods ($3 \cong 1/0.36$). Additionally, when evaluating the statistics related to the model's validity, it is evident that there are no issues with heteroskedasticity or serial correlation.

CUSUM and CUSUMSQ test are applied to examine the stability of the obtained long-term coefficients, which are given in Figure 2.

**Figure 2.** CUSUM and CUSUMSQ tests results

As shown in Figure 2, the CUSUM and CUSUMSQ test graphs remain within the 5% significance boundaries, indicating that the long-term coefficients are stable. The applied test confirms the model's effectiveness, allowing for reliable interpretation of the long-term coefficients.

In Table 3, it is seen that the coefficient of RE/NRE+ variable is significant and negative (-2.08). According to this, one unit increase in RE/NRE ratio will decrease the ESRI variable by two units. Since the increase in the ratio (RE/NRE) depends on either an increase in renewable energy usage or a decrease in non-renewable energy usage, getting greener is the key to energy supply security.

5. CONCLUSION AND POLICY IMPLICATIONS

Energy is the most fundamental and essential input for modern societies, and as such, countries strive to secure reliable sources of energy, particularly fossil fuels. These fuels, including oil, natural gas, and coal, make up a significant portion of global energy consumption. However, the use of fossil fuels has led to three critical issues. Firstly, these sources are non-renewable and will eventually run out. Secondly, the burning of fossil fuels releases greenhouse gases, contributing to environmental pollution. Finally, fossil fuels exhibit geographic concentration, resulting in an uneven distribution across regions. Nations lacking ample indigenous energy resources must fulfill their energy requirements through external sources. Furthermore, reliance on a limited number of energy sources and supplier countries increases the vulnerability of these nations to potential energy shortages. To address these problems, researchers have explored alternative energy sources such as renewable and nuclear energy. Despite these efforts, a significant reduction in the use of fossil fuels is not expected until the middle of the 21st century.

The issue of energy is complex, sensitive, and significant, requiring a comprehensive perspective that considers political, economic, and technological dimensions. In countries with surplus energy resources, the focus is on finding, extracting, transporting, processing, and selling excess energy. However, in countries with insufficient energy resources to meet their needs, the key issue is ensuring uninterrupted and safe energy supply through reliable channels at reasonable prices. For such countries, the primary agenda in energy policy is to guarantee energy supply security by diversifying imported energy sources and supply channels, reducing reliance on non-renewable energy resources, and increasing the use of renewable and nuclear energy sources.

The objective of this study is to develop a sensitive and realistic index to calculate the level of energy supply risk. Firstly, the necessary steps were followed to create this new index. The resulting index will facilitate accurate measurement of energy supply security, which has remained a pressing concern globally in recent years. Furthermore, this index will assist in identifying potential risks in energy supply security and enable efficient selection and implementation of appropriate policies to address these risks.

After creating the index, we conducted an econometric analysis to test its applicability. The analysis examined the effects of renewable and non-renewable energy consumption on the index. The results showed that increasing the consumption of renewable energy sources relative

to non-renewable energy sources has a positive effect on energy supply security. These empirical findings confirm the theoretical expectation that encouraging investments in domestic and renewable energy resources and increasing their share in energy consumption can have positive political, economic, and technological impacts on Türkiye by reducing the energy supply risk.

RESEARCHERS' CONTRIBUTION RATE STATEMENT

The contribution rates of the authors in the study are equal.

CONFLICT OF INTEREST STATEMENT

There is no conflict of interest within the scope of the study.

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