Cilt: 12 Sayı: 1, 2025, ss. 171-189

PAMUKKALE ÜNİVERSİTESİ
İŞLETME ARAŞTIRMALARI DERGİSİ (PIAR)
Pamukkale University Journal of Business Research
https://dergipark.org.tr/tr/pub/piar

The Relationship of Energy Consumption and Economic Growth under Structural Break: An Application on Türkiye [1]

Yapısal Kırılma Altında Enerji Tüketimi ve Ekonomik Büyüme İlişkisi: Türkiye Üzerine Bir Uygulama

Mahir TOSUNOĞLU [1] **Halil UÇAL [2*]**

[1] Ege University, mtosunoglu00@gmail.com, ORCID: 0000-0002-9941-0151
[2] Pamukkale University, hucal@pau.edu.tr, ORCID: 0000-0002-1475-2962
[*] Yazışılan Yazar/Corresponding Author

Makale Geliş/Received: 09.05.2025 Makale Kabul/Accepted: 03.06.2025

Araştırma Makalesi / Research Paper DOI: 10.47097/piar.1696046

Abstract

It is known that oil crises caused great economic distress in the world after the 1970s. These crises were caused by problems related to energy supply and created a more debatable environment for the relationship between economy and energy. During this period, discussions on the concepts of energy and economic growth increased among economists. This study aims to contribute to the discussions in the EC (energy consumption) and EG (economic growth) literature from the perspective of biophysical theory. In this study, the effect of EC on EG and the effect of EG on EC for the period 1970-2019 in Türkiye were examined using Zivot-Andrews unit root, Gregory-Hansen cointegration, DOLS, FMOLS, CCR and Granger causality analysis methods. With these methods, the complex structure of long-term relationships and causality relationships were examined in depth by taking into account structural breaks in Türkiye. The findings revealed that there was a cointegration relationship between EC and EG. The structural break year was found to be 2010 and it was seen that the effects of the global economic crisis continued. When the long-term coefficients are examined, a 1% increase in EC increases EG by 0.37%, 0.72% and 0.69%, respectively, according to DOLS, FMOLS and CCR estimators. In addition, EC is the Granger cause of EG. It was seen that the growth hypothesis is valid in Türkiye. The establishment of policies that support the increase in energy investments in Türkiye has the potential to contribute to a stable economic growth.

Keywords: *Energy Economics, Zivot Andrews, Gregory Hansen, DOLS, FMOLS, CCR.*

Jel Codes: *A10, B22, C32.*

Öz

Petrol krizlerinin 1970'li yıllardan sonra Dünya'yı büyük bir ekonomik sıkıntıya soktuğu bilinmektedir. Bu krizler, enerji arzıyla ilgili sorunlardan kaynaklanmış olup, ekonomi ve enerji arasındaki ilişkiyi daha fazla tartışma ortamı oluşturmuştur. Bu dönemde, ekonomistler arasında enerji ve ekonomik büyüme kavramları üzerine yapılan tartışmalar artmıştır. Bu çalışma, EC (enerji tüketimi) ve EG (ekonomik büyüme) literatüründeki tartışmalara, biyofiziksel teorinin bakış açısından katkıda bulunmayı amaçlamaktadır. Bu çalışmada, Türkiye'de 1970-2019 dönemi için EC'nin EG üzerindeki etkisi ve EG'nin EC üzerindeki etkisini Zivot-Andrews birimkök, Gregory-Hansen eş-bütünleşme, DOLS, FMOLS, CCR ve Granger nedensellik analizi yöntemleriyle incelenmiştir. Bu yöntemlerle Türkiye'de yapısal kırılmalar dikkate alınarak uzun dönem ilişkiler ve nedensellik ilişkilerinin karmaşık yapısı derinlemesine incelenmiştir. Bulgular, EC ile EG arasında eş-bütünleşme ilişkisi tespit edilmiştir. Yapılsal kırılma yılı 2010 bulunarak küresel ekonomik krizin etkilerinin devam ettiği görülmüştür. Uzun dönem dönem katsayılarına bakıldığında EC'de yaşanacak %1'lik bir artış DOLS, FMOLS ve CCR tahmincilerine göre sırasıyla %0.37, %0.72 ve %0.69 EG'yi arttırmaktadır. Ayrıca, EC'nin EG'nin Granger nedenidir. Türkiye'de büyüme hipotezinin geçerli olduğu görülmüştür. Türkiye'de enerji yatırımlarının artmasını destekleyen politikaların oluşturulması, istikrarlı bir ekonomik büyümeye katkı sağlama potansiyeline sahiptir.

Anahtar Kelimeler: *Enerji Ekonomisi, Zivot Andrews, Gregory Hansen, DOLS, FMOLS, CCR.*

Jel Kodları: *A10, B22, C32.*

Atıf için (Cite as): Tosunoğlu, M., & Uçal, H. (2025). The relationship of energy consumption and economic growth under structural break: An application on Türkiye. *Pamukkale Üniversitesi İşletme Araştırmaları Dergisi, 12*(1), 171-189. https://doi.org/10.47097/piar.1696046

[1] This study was derived from master thesis of Mahir Tosunoğlu.

1. INTRODUCTION

After the 1970s, the thesis of the infinity of energy resources and ease of transportation, which was widespread in the world, disappeared when Organization of Arab Petroleum Exporting Countries (OAPEC) members decided to reduce oil production. This decision taken in the 70s led to a major economic crisis in the world. During this period, many countries experienced economic contraction. After this crisis, the concepts of E (energy) and EG (economic growth) have become more frequently mentioned together. When we go towards the origin of the concept of energy in economic terms, it is seen that this issue has been around since the physiocrats. Physiocrats believed that the basis of the economy was agriculture. In this context, although the importance of energy in terms of economy is not directly related to energy resources, they emphasised the importance of soil and water and thought that wealth would be achieved through agricultural production. Therefore, they gave importance to energy sources such as sun and wind, which affect agricultural production. It can be said that the introduction of energy into economic theory is with the physiocrats (Ayres et al., 2013). When the concepts of E and EG are examined together, it is seen that in classical growth theories, labour and capital are focused on and energy resources are seen as intermediate goods and they are not emphasized much. When considering why energy is not traditionally regarded as a factor of production, it's due to the belief that economic growth and technological advancements will prevent the depletion of natural resources, market failures will be rectified by factoring in the costs of natural resources, and human-made capital will indefinitely replace natural capital (Tartari, 2023; Cheng and Andrews, 1998). Towards the end of the 1980s, biophysical economics came to the fore with its interdisciplinary and environmentalist research. Biophysical economists emphasised the importance of energy for economic growth and even stated that energy played a critical role in the industrial revolution. According to Georgescu-Roegen (1976), one of the biophysical economists, energy is a fundamental factor of production and when energy resources are depleted, growth may slow down or even stop due to the inability to renew itself. Biophysical economists argue that inputs such as labour and capital arise from the mobility of energy, i.e. the flow of energy. Therefore, they state that energy consumption is very important in the productivity of both capital and labour factors and that it contributes directly to production (Kennedy, 2022; Stern, 2010; Ockwell, 2008; Hall and Klitgaard, 2006; Alam, 2006; Hussen, 2004). Energy dependence stands out as a determining factor in the relationship between Türkiye's EC and EG. Turkiye is a country that meets most of its Energy needs from external sources, especially fossil fuels such as oil and natural gas. This high external dependence makes EG vulnerable to fluctuations in global energy prices and geopolitical risks. Energy imports are an important component of the current account deficit and can threaten macroeconomic stability. Therefore, it is critical for Turkiye to increase energy supply security, invest in domestic and renewable energy resources and improve energy efficiency in order to achieve its sustainable economic growth targets. Reducing energy dependence not only helps stabilize EG but also makes the economy more resilient to external shocks (Tosunoğlu and Uçal, 2025; Gunes and Erol, 2024; Dam and Sarkodie, 2023).

In this study, the effect of EC on EG and the mutual effects of EG on EC for the period 1970 to 2019 in Türkiye were examined within the scope of biophysical theory and examined using Zivot-Andrews unit root, Gregory-Hansen cointegration, DOLS, FMOLS, CCR and Granger causality analysis methods. The relationship between EC and EG is approached from the perspective of classical economics in the existing literature. However, this situation is insufficient to explain the complex relationship between EC and EG. This study aims to make an original contribution to the literature by examining the relationship between EC and EG from the perspective of physiophysical theory by taking structural breaks into account. This study consists of four main sections. The first section presents a literature review of the related study. The second section outlines the methodological approach followed in the estimation process. In the third section, the variables, data sets and the empirical model are introduced in detail, the findings are presented and a comprehensive evaluation is made in light of the findings of the analysis. The last section, the fourth section, summarizes the overall results of the study and makes recommendations for policymakers in line with the findings.

2. LITERATURE REVIEW

In the reviewed literature, the pioneering study on EC and EG is the paper by Kraft and Kraft (1978). This study analyzed the period 1950-1970 in the US economy using the Sims technique and identified a unidirectional causal relationship from EG to EC. Subsequently, Yu and Jin (1992) examined the 1974-1990 period in the US economy with cointegration and Granger causality analysis methodsIn this paper, a unidirectional causal relationship was identified from EC to EG.

Later on, Stern (1993) again chose a wider period of analysis, i.e. 1947-1990 in the US economy. In this study, using Multivariate VAR and Granger Causality analyses, he found a unidirectional relationship from EC to EG. Cheng (1995) and Stern (2000) also examined the US economy with cointegration and Granger causality analyses. Cheng (1995) found a unidirectional relationship from EG to EC, while Stern (2000) found a reciprocal causality relationship between EC and EG.

The groundbreaking studies have been examined in the context of the US economy. It was observed that time series analysis methods, especially cointegration and Granger causality analyses, were used as methods. In the subsequent studies, cointegration (Johansen, ARDL, Bayer-Hanck) and causality analyses (Granger, Toda-Yamamoto, Dolado-Lütkepohl) were used. As for Lu (2017), co-integration and Granger causality analyses were applied again by using panel data analysis method. In this study, EC and EG were found to be cointegrated. In addition, a mutual causality relationship was also detected.

Upon reviewing the general characteristics of the literature, it is evident that cointegration and causality relations between EC and EG have been extensively explored. Most studies involve time series analyses, although there are some that utilize panel data analysis. While the majority of studies conclude the existence of a long-run relationship between the variables, the results of causality analysis vary depending on the regions studied. The main literature summary of the reviewed literature is as follows;

Table 1. Empirical Literature Summary

Author(s)	Variables	Country and Period	Method	Findings
Kraft and Kraft (1978)	EC, GNP	USA 1947-1974	Sims Methodology, F test	It is a pioneering work. Y→ E
Yu and Jin (1992)	EC, GDP	USA 1974-1990	Co-integration Analysis, Granger Casualiy Test	E→ Y
Stern (1993)	EC, GDP	USA 1947-1990	Granger Casualiy Test, Multivariate VAR Analysis	E→ Y
Cheng (1995)	EC, GDP	USA 1947-1990	Co-integration Analysis, Granger Casualiy Test	Y→E
Stern (2000)	EC, GDP	USA 1948-1994	Co-integration Analysis, Granger Casualiy Test	E↔ Y
Yang (2000)	EC, GDP	Taiwan 1954-1997	Granger Casualiy Test	E↔ Y
Ghosh (2002)	per capita ELC, per capita real GDP	Indian 1950-1997	Johansen Co-integration Analysis, Granger Casualiy Test	The variables are cointegrated. Y→ E
Shiu and Lam (2004)	ELC, real GDP	Chinese 1971-2000	Johansen Co-integration Analysis, Granger Casualiy Test, ECM	The variables are cointegrated. E→ Y
Yoo (2005)	ELC, real GDP	Korean 1970-2002	Co-Integration Analysis, ECM	E↔ Y
Narayan and Smyth (2005)	per capita ELC, Emp, per capita real GDP	Australia 1966-1999	Co-integration Analysis, Granger Casualiy Test	Variables are cointegrated. Y→ E Y→ Emp
Zou and Chau (2006)	OC, EG	Chinese 1953-2002	Co-integration Analysis, Granger Casualiy Test	Oil consumption and GDP are cointegrated. E≁ Y
Ho and Siu (2007)	ELC, real GDP	Hong Kong 1966-2002	Co-integration Analysis, Granger Casualiy Test and VECM	Variables are cointegrated. E→ Y
Ang (2007)	EC, CO_2, GNP	France 1960-2000	VECM, Co-integration Method	Variables are cointegrated. E→ Y
Lise and Van Montfort (2007)	EC, GDP	Türkiye 1970-2003	Co-integration Analysis, Granger Casualiy Test	EC and GDP are co-integrated. Y→E
Ciarreta and Zarraga (2009)	ELC, real GDP	Spain 1971-2005	Co-integration Analysis (Dolado-Lütkepohl and Toda-Yamamoto), Granger Casuality Test	Y→ E
Bowden and Payne (2009)	EC, real GDP	USA 1949-2006	Toda-Yamamoto Casualiy Test, Granger Casualiy Test	E→ Y
Gupta and Sahu (2009)	ELC, EG	India 1960-2006	Granger Casualiy Test	E→ Y

Table 1. Empirical Literature Summary (Continued)

Author(s)	Variables	Country and Period	Method	Findings
Vecchione (2010)	ELC real GDP	Italy 1963-2007	VECM, Granger Casualiy Test	Y→ E
Tsani (2010)	EC, real GDP	Greece 1960-2006	Toda Yamamoto Casuality Test	E→ Y
Gurgul and Lach (2012)	ELC, real GDP	Poland 2010-2009 (quarterly)	Johansen Co-integration Analysis, VECM, Granger Casualiy Test	The variables are cointegrated. E↔ Y
Yazdan and Hossein (2012)	OC, EG	Iran 1980-2010	Co-integration analysis, ARDL, ECM, Granger Casualiy Test	For the short run: Y→E For the long run: E↛Y
Tang et al. (2013)	per capita ELC, per capita real GDP	Portugal 1974-2009	ARDL Bounds Analysis, VECM, Co-integration Analysis, Granger Casualiy Test	The variables are cointegrated. E↔ Y
Park and Yoo (2014)	OC, real GDP	Malaysia 1965-2011	Co-integration analysis, VECM, Granger Casualiy Test	Oil consumption and real GDP are cointegrated. E↔ Y
Kyophilavong (2015)	EC, FTD, EG	Thailand 1971-2012	Bayer-Hanck Co-integration Analysis, Granger Casualiy Test	The variables are cointegrated. E↔ Y E↔ FTD
Salahuddin and Alam (2015)	per capita ELC, per capita real GDP	Australia 1985-2012	Zivot-Andrews Test, ARDL Bounds Analysis and VECM	Y→ E
Ikegami and Wang (2016)	ELC, real GDP	Germany and Japan 1996:04-2015:02	ARDL Bounds Test, Granger Casualiy Test	ELC and real GDP are co-integrated. For Germany: Y→ E For Japan: E→ Y
Lu (2017)	IEC, real GDP (Industry)	Taiwan 1998-2014	Co-integration Analysis (Panel) and Granger Causality Test	The variables are cointegrated. E↔ Y
Han (2022)	REC, EG	E7 counries 1990-2018	Emirmahmutoğlu and Köse causality test	E↔ Y
Örnek and Kabak (2023)	REC, EG	Türkiye 1990-2020	Granger Casualiy Test	Y→ E

Relationship Direction: "→" The direction of the one-sided relationship, "↔" bilateral relationship and "↛" It represents unrelatedness.
Variable Abbreviations: Cap: Capital, CO_2: Carbondiocixde, DEF: Deficit, EC: Energy Consuption, REC: Renewable Energy Consuption, EG: Economic Growth, ELC: Electricity Consumption, Exp: Export, FD: Financial Development, FTD: Foreign Trade Deficit, GDP: Gross Domestic Product, GNP: Gross National Product, Imp: Import, IEC: Industrial Electricity Consumption, IT: International Trade, OC: Oil Consumption.
Methot Abbreviations: ECM: Error Correction Model, VECM: Vector Error Correction Model.

Hypothesis Abbreviations: CH: Conservation Hypothesis, FH: Feedback Hypothesis, GH: Growth Hypothesis, NH: Neutrality Hypothesis.

Although numerous empirical studies have investigated the causal relationship between energy consumption (EC) and economic growth (EG) in various countries using diverse econometric methods, most of them have approached this nexus through the lens of classical economic theory, often assuming linear and stable relationships over time. Moreover, only a limited number of studies have focused specifically on Türkiye, and those that do (e.g., Lise and Van Montfort, 2007) generally overlook structural breaks, energy dependency dynamics, and evolving global energy market conditions. Additionally, the literature predominantly treats energy as an economic input, without adequately considering the broader ecological and systemic implications of consumption patterns. In this context, there remains a significant gap in the literature regarding the examination of the EC–EG relationship in Türkiye by incorporating both structural breaks and the biophysical perspective, which considers the physical limits and environmental consequences of energy use. This study addresses this gap by employing advanced time-series methods that account for structural shifts while reinterpreting the EC–EG link within a biophysical theoretical framework, offering a more comprehensive and context-sensitive understanding of the Turkish case.

3. METHODOLOGY

3.1. Zivot-Andrews (ZA) Unit Root Test

Unlike Perron (1989), where the structural break is exogenously determined, Zivot-Andrews (ZA) test is a unit root test designed to detect a single structural break, allowing for endogenous identification of the structural break. The observation where the smallest t-statistic is obtained is determined as the break time. The ZA unit root test is estimated based on three models. Model A refers to a structural break at the level, Model B at the slope and Model C at both the slope and level (Zivot and Andrews, 1992: 254).

If the t-statistic value obtained from the one-tailed t-test is less than the ZA critical value computed by Zivot and Andrews (1992), the null hypothesis of a unit root in the presence of a structural break is rejected.

Equations (1), (2), and (3) present Model A, Model B, and Model C as follows (Zivot and Andrews, 1992:254):

Model A: $y_t = \mu + \beta_t + \alpha y_{t-1} + \theta_1 DU(\varphi) + \sum_{i-1}^{k} c_i \Delta y_{t-i} + e_t$ (1)

Model B: $y_t = \mu + \beta_t + \alpha y_{t-1} + \theta_2 DT(\varphi) + \sum_{i-1}^{k} c_i \Delta y_{t-i} + e_t$ (2)

Model C: $y_t = \mu + \beta_t + \alpha y_{t-1} + \theta_2 DT(\varphi) + \theta_1 DU(\varphi) + \sum_{i-1}^{k} c_i \Delta y_{t-i} + e_t$ (3)

In the equations, t = 1,2...,T is the time, T_B is the break time and $\tau = T_B/T$ is the break point. In addition, DU_t is the dummy variable representing the break in the mean, and DT_t is the dummy variable indicating the break in the trend. Explanations of these shadow variables are given below;

$$DU_t = \begin{cases} 1 \rightarrow t > TB \\ 0 \ \rightarrow other \end{cases}$$

$$DT_t = \begin{cases} (t - TB) \rightarrow t > TB \\ 0 \qquad \rightarrow other \end{cases}$$

DU_t denotes the break in the mean in the constant term, which takes the value 1 when t>TB and 0 in other cases. DU_t denotes the dummy variable for the break in the trend, which takes the value $t - TB$ when $t > TB$ and 0 otherwise. The addition of Δy_{t-i} to the equations is intended to address the potential autocorrelation issue that may arise in the error terms.

3.2. Gregory-Hansen Cointegration Test

The co-integration test devised by Gregory and Hansen (1996) is a test that endogenously identifies the structural break and permits a single structural break. In this test, the long-run relationship between the time series is investigated based on three different models. Model 1 refers to constant break (C), Model 2 refers to constant break with trend (C/T) and Model 3 refers to regime change (C/S). The explanations for Model 1, Model 2, and Model 3 are provided as follows (Gregory and Hansen, 1996: 103):

Model 1 (C):

$$\gamma_{1t} = \mu_1 + \mu_2\varphi_{tr} + \alpha^T\gamma_{2t} + \varepsilon_t \qquad t = 1, \dots, n \tag{4}$$

Model 2 (C/T):

$$\gamma_{1t} = \mu_1 + \mu_2\varphi_{tr} + \beta t + \alpha^T\gamma_{2t} + \varepsilon_t \qquad t = 1, \dots, n \tag{5}$$

Model 3 (C/S):

$$\gamma_{1t} = \mu_1 + \mu_2\varphi_{tr} + \alpha_1^T\gamma_{2t} + \alpha_2^T\gamma_{2t}\varphi_{tr} + \varepsilon_t \qquad t = 1, \dots, n \tag{6}$$

In these equations, μ_1 and $\mu_2$are the same as the model showing the break in the constant. Here, α_1 represents the slope coefficient before the break, whereas α_2 denotes the change in the slope coefficient after the break (Gregory and Hansen, 1996: 103).

The date at which the Phillips test statistics and ADF test statistics calculated for the above three models are minimum is determined as the appropriate break point of the cointegration test (Gregory and Hansen, 1996: 106).

The test statistics determined according to the above models are compared with the table critical values determined according to the number of variables in Gregory and Hansen's 1996 study and accordingly, the alternative hypothesis that there is a co-integration relationship between the series with one structural break is tested against the hypothesis that there is no co-integration relationship between the series.

3.3. FMOLS, DOLS, CCR

As a conclusion of the Gregory-Hansen test, long-run and short-run relationships will be investigated in this section using specific methods. In the study, DOLS, FMOLS and CCR cointegration methods, in which structural breaks can be included in the analysis as dummy variables, are used. FMOLS, CCR, and DOLS cointegration methods, similar to traditional cointegration methods, rely on the assumption that the series utilized are stationary in difference. The standard errors of the coefficients of a model estimated by the traditional ECM method are biased. Therefore, DOLS (Dynamic Ordinary Least Squares), FMOLS (Fully Modified OLS), and CCR (Canonical Cointegrating Regression) cointegration methods are employed to estimate and interpret the long-run coefficients of the independent variables once the cointegration relationship is identified. The DOLS estimator developed by Stock and

Watson (1993) is proficient in mitigating the biases stemming from the endogeneity issue between the independent variables and the error term. Conversely, the FMOLS estimator developed by Hansen and Phillips (1990) is adept at alleviating biases arising from both endogeneity problems and collinearity between the independent variables and the error term. The CCR estimator developed by Park (1992) is an estimator used to eliminate the deviations arising from the traditional ECM method. The CCR estimator uses the long-run covariance matrix of the variables transformed with the long-run covariance matrix to eliminate the deviations in the EKK method, and the reason for this is to asymptotically eliminate the endogeneity arising from correlation in the long run (Mehmoo et al. 2014: 9).

3.4. Granger Causality Analysis

Granger causality analysis is a test that tries to understand the relationship between two time series by using the past values of the series. Therefore, Granger causality analysis is obtained by utilising the Vector auto-regressive (VAR) model as follows;

$$Y_t = \alpha_0 + \sum_{i=1}^{k1} \alpha_i Y_{t-i} + \sum_{i=1}^{k2} \beta_i X_{t-i} + \varepsilon_t \tag{7}$$

$$X_t = \gamma_0 + \sum_{i=1}^{k3} \gamma_i Y_{t-i} + \sum_{i=1}^{k4} \delta_i X_{t-i} + \emptyset_t \tag{8}$$

X and Y are two stationary time series, α and γ are the constant terms, ε_t and $\emptyset_t$ are the error terms with white noise process and kj, j=(1,2,3,4) represent the maximum lag lengths determined by the VAR method in each time series.

According to Granger (1969), if incorporating past values of X when forecasting Y yields superior results compared to not incorporating them, then X is deemed to be the Granger cause of Y. In this case, the direction of Granger causality is from X to Y and is unidirectional. Simultaneously, if employing past values of Y when forecasting X yields superior outcomes, then the relationship is bidirectional. If, however, X is not a Granger cause of Y, and likewise, Y is not a Granger cause of X, then the two variables are statistically independent.

4. EMPIRICAL ANALYSIS RESULTS

4.1. Model and Data Set

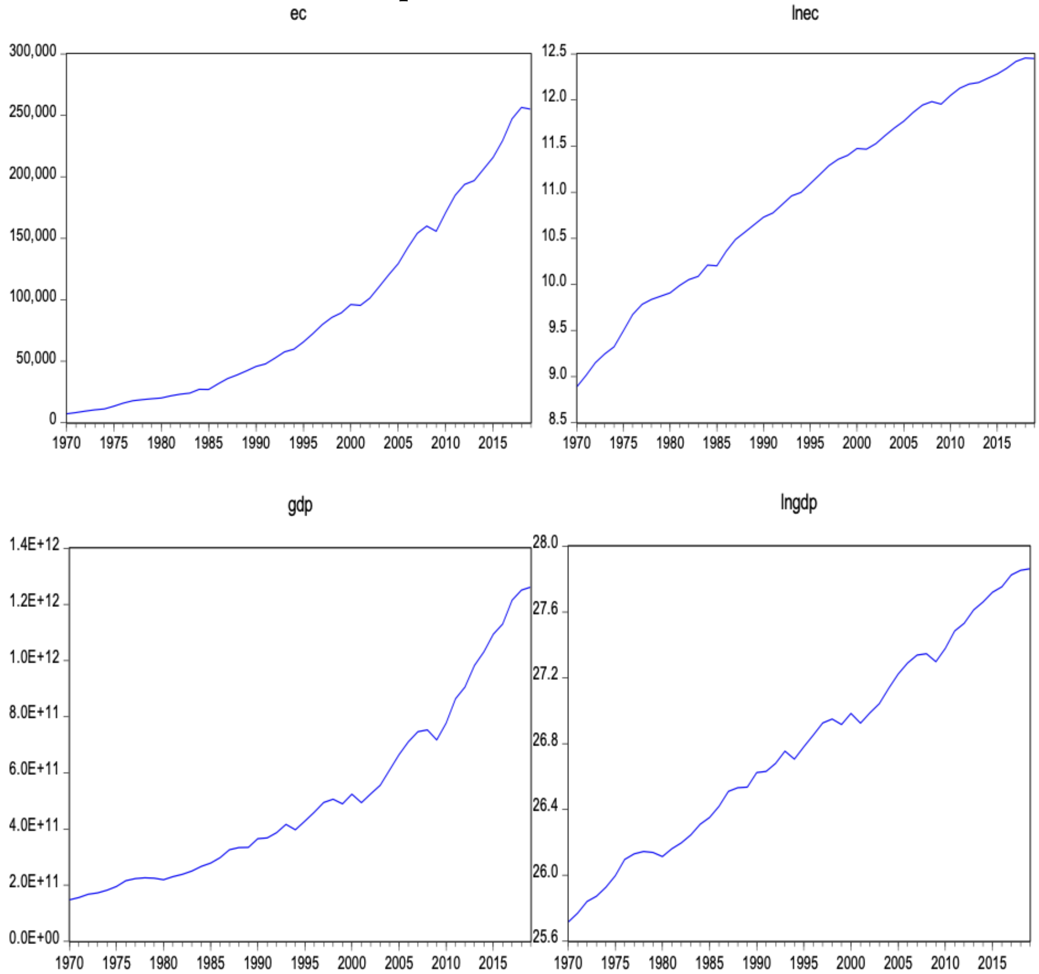
The logarithmic form of real GDP (=2010 US$) and total final electricity consumption (gwh) 1970-2019 annual data are used in the study. Real GDP data are sourced from the World Bank Development Indicators (WDI), while total final electricity consumption data are sourced from the World Energy Council Turkish National Committee (WECT) balance tables. The analyses were conducted using Eviews 10 software. The models used to estimate the relationship between the relevant variables are as follows:

$$lnGDP = f(lnEC) \tag{9}$$

$$lnEC = f(lnGDP) \tag{10}$$

While $lnGDP$ is the natural logarithm of real GDP, $lnEC$ is the natural logarithm of total final electricity consumption. The reason for using the natural logarithm of the variables in the model (double-log model) is both to minimise the scale and because the estimated coefficients can be interpreted as elasticity. The graphs depicting the variables utilized in the model are presented below:

Graph 1. Views of Variables



4.2. Results of Empirical Analysis

In this research, ADF and PP unit-root test conclusions for real GDP and total final electricity consumption variables in logarithmic form for Türkiye for the years 1970-2019 are as follows:

Table 2. Augmented DF and Phillips-Perron Unit-Root Test Results

	Augmented Dickey-Fuller			Phillips-Perron		
Variable	**None**	**Intercept**	**Trend & Intercept**	**None**	**Intercept**	**Trend & Intercept**
Lnec	3,59 (0,99)	-3,84* (0,0047)	-1,59 (0,7814)	7,39 (0,99)	-4,10* (0,00)	-1,59 (0,78)
Lngdp	7,71 (0,99)	-0,12 (0,9407)	-2,68 (0,25)	7,94 (0,99)	-0,12 (0,94)	-2,81 (0,20)
Δ lnec	-1,53 (0,12)	-5,09* (0,00)	-6,14* (0,00)	-2,49** (0,01)	-5,06* (0,00)	-6,08* (0,00)
Δ lngdp	-2,40** (0,02)	-4,80* (0,00)	-4,79* (0,00)	-3,74* (0,00)	-6,70* (0,00)	-6,62* (0,00)

Notes: When determining the lag number of the ADF test, the maximum lag number is taken as 2 and the t-statistic criterion at 10% significance level is used, Values in parentheses are probability values, *, ** and *** denote critical values at 1%, 5% and 10% significance levels, respectively, In the PP test, "Bandwidth" was determined according to the Newey-West method and Barttlet Kernel estimator was used.

When the ADF and PP results are evaluated, when the level values of the total final electricity consumption variable in logarithmic form are considered, it is observed that the series contains unit root for the model without constant term-without trend and with constant term-with trend, while the series is stationary for the model with constant term. When the level values of the real GDP variable are analysed, it is observed that the series contains unit root in all three models. When the difference values of the two variables are analysed, it is found that the variables are stationary in their first differences in all three models. A unit root process in a series may arise from a structural break in that series. In the following section, it will be investigated whether there is a unit root process arising from any structural break.

Table 3. Zivot-Andrews Test Results

Variable	Model A (t-ist)	Model A Break Time	Model C (t-ist)	Model C Break Time
Lnec	-3,25	1986	-3,30	2008
lngdp	-3,82	2011	-4,11	1999
Δlnec	-6,83*	1978	-7,01*	1986
Δlngdp	-5,25**	2004	-5,26**	1983
Critical Values	**Model A Critical Values**		**Model C Critical Values**	
%1	-5,34		-5,57	
%5	-4,93		-5,08	
%10	-4,58		-4,82	

Notes: t-ist, denotes t-statistic values, *, ** and *** denote critical values at 1%, 5% and 10% significance levels, respectively, For the related critical values, see Zivot and Andrews (1992),

Model A examines the break in the series' constant, while Model C assesses the break in both the series' constant and trend. Based on these findings, the test statistic values for both Model A and Model C series surpass the critical values at various significance levels. Consequently, for both Model A and Model C, the null hypothesis of a unit root in the presence of a structural break in the logarithmic series of total final electricity consumption and real GDP cannot be rejected at significance levels of 1%, 5%, and 10%. This implies that the variables possess a unit root at their level values when a structural break is considered. However, when examining the differenced values of these variables, which exhibit a unit root under structural break, the test statistic values for both Model A and Model C series fall below the critical values. Consequently, for both Model A and Model C, the null hypothesis that a unit root exists when a structural break is present is rejected at a significance level of 1% for total final electricity consumption and 5% for real GDP. In other words, the variables exhibit stationarity in their differenced values under a structural break. When considering the results of the ADF, PP, and Zivot-Andrews tests together, it can be concluded that the logarithmic form series of total final electricity consumption and real GDP, denoted as "lngdp" and "lnec" respectively, are integrated of order one, or I(1). These findings indicate the potential application of the Gregory-Hansen structural break cointegration technique.

Table 4. Gregory-Hansen Cointegration Test Results

Dependent Variable	Model	ADF		Critical Values	
		Break Time	**ADF Stat**	**%1**	**%5**
lngdp	Break in Constant (C)	2009	-3,82 (2)	-5,13	-4,61
	Break in Constant and Trend (C/T)	2010	-5,29 (3)	-5,45	-4,99
	Regime Change (C/S)	2006	-4,51 (2)	-5,47	-4,95
lnec	Break in Constant (C)	2009	-3,68 (2)	-5,13	-4,61
	Break in Constant and Trend (C/T)	2011	-3,29 (0)	-5,45	-4,99
	Regime Change (C/S)	2006	-3,97 (2)	-5,47	-4,95

Notes: See Gregory and Hansen (1996:109) for the related critical values, The values in parentheses indicate the number of lags selected by the Akaike Information Criterion,

The table above presents the results of the Gregory-Hansen cointegration analysis, which focuses on endogenously determined and structurally break-integrated relationships. Based on the findings, when the dependent variable is "lngdp," the hypothesis of no cointegration relationship under a structural break is rejected for the model with a break in both the constant and trend (C/T), as the computed minimum absolute ADF statistic is greater than the critical value at the 5% level. Thus, the alternative hypothesis indicating a cointegration relationship with a structural break is accepted. However, the fundamental hypothesis indicating no cointegration between series cannot be rejected for the models with a break only in the constant (C) and with regime change (C/S). For the dependent variable "lnec," the computed minimum absolute ADF statistic is smaller than the critical values, implying that the fundamental hypothesis of no cointegration between series cannot be rejected. According to the analysis results, it is possible to infer the existence of a long-term co-integration relationship between real GDP and total final electricity consumption based on the available data. Consequently, when the dependent variable is "lngdp," the coefficients for both long- and short-term cointegration can be estimated. In the conducted study, while performing the long-term analysis, the breakpoint obtained from the Gregory-Hansen cointegration test was included in the model as a structural break dummy variable. The breakpoint used in the model was determined based on the conclusions of the Gregory-Hansen cointegration analysis, reflecting the specific breakpoint where the cointegration relationship exists. This dummy variable was constructed according to the 2010 breakpoint: it was set to zero for years up to the breakpoint and set to one for the subsequent years. The following table presents the coefficients obtained by using DOLS, FMOLS and CCR cointegration estimators when lngdp and lnec are the dependent variables and when both are independent variables.

Table 5. Long Run Cointegration Coefficients Results

	DOLS		FMOLS		CCR	
Dependent Variable	**lnec**	**d1**	**Lnec**	**d1**	**lnec**	**d1**
Lngdp	0,368* (0,01)	0,008 (0,34)	0,716* (0,00)	0,032* (0,00)	0,689* (0,00)	0,030* (0,00)

Notes: The values in parentheses indicate the probability value and *, ** and *** indicate that the coefficients are statistically significant at 1%, 5% and 10% significance levels, respectively, The autocorrelation problem in the estimation is solved by differencing, In the analysis, d1:2010 is taken as a dummy variable,

When the long-run cointegration coefficients in the table above are analysed; while logarithmically real GDP is the dependent variable and aggregate final electricity consumption is the independent variable, according to the DOLS, FMOLS and CCR results; the long-run coefficient of EC against EG variable is statistically significant. In the long run, there exists a positive relationship between the variables. In Türkiye, a 1% increase in EC increases EG by 0,37%, 0,72% and 0,69% respectively. Our dummy variable used in DOLS, FMOLS and CCR cointegration analysis is statistically significant. The Gregory-Hansen cointegration method indicates that there were significant changes in the Turkish economy in 2010. When the developments in 2010 are analysed, the Mortgage Crisis, which deeply affected the world economy, and the global financial crisis that occurred between 2007 and 2008 come to the fore. The effects of this global multinational financial crisis were experienced between 2007 and 2010. The structural breakpoint of 2010 identified in the study can be evaluated as an important turning point for the Turkish economy. This date coincides with a period when significant transformations were experienced in Türkiye's energy policies and economic structure. After 2010, developments such as strategic investments aimed at increasing energy supply security, acceleration of renewable energy projects and activation of energy efficiency policies were observed in Türkiye. In addition, 2010 was a period in which recovery after the global financial crisis and growth driven by domestic demand came to the fore in economic growth dynamics. The determination of the structural break shows that the relationship between EC and EG gained a different dynamic from this date onwards and the effect of energy use on growth in the economy became stronger. Therefore, the structural break of 2010 can be interpreted as a statistical reflection of structural changes experienced in Türkiye's energy economy policies and economic growth model. In this context, the methodology of the study that takes structural breaks into account makes an important contribution in terms of revealing the sensitivity of the Turkish economy to periodicity and policy changes. The short-run analysis was carried out within the framework of the error correction model, using the differenced series and the one-period lagged value of the error term series (ECT_{t-1}) obtained from the long-run analysis, again with DOLS, FMOLS and CCR methods. The coefficients obtained from the short-run analysis are presented in the table below.

Table 6. Error Correction Model Coefficients Results

	DOLS		FMOLS		CCR	
Dependent Variable	**Δlnec**	**ECT_{t-1}**	**Δlnec**	**ECT_{t-1}**	**Δlnec**	**ECT_{t-1}**
Δlngdp	-0,33 (0,27)	0,49 (0,33)	0,20*** (0,07)	-0,30** (0,04)	0,24** (0,04)	-0,69* (0,00)

Notes: The values in parentheses indicate the probability value and * and ** indicate that the coefficients are statistically significant at 1% and 5% significance level, respectively,

When the error correction coefficients (ECT_{t-1}) in the table above are analysed, it is seen that the coefficient of the ECT for FMOLS and CCR is negative (between -1 and 0) and statistically significant, i.e. the error correction mechanism works. When the results obtained according to the DOLS method are evaluated, the error correction model does not work for the DOLS method since the calculated error correction term is statistically insignificant. Based on the FMOLS and CCR results, according to the FMOLS estimator, a short-run deviation between the variables that move together in the long-run is eliminated after 3,33 (1/0,30) years and reaches the long-run equilibrium, while according to the CCR estimator, a short-run deviation between the variables that move together in the long-run is eliminated after 1,44 (1/0,69) years and reaches the long-run equilibrium. During the VAR-Granger causality test, stability of roots, stationarity, autocorrelation and variance tests were performed while determining the appropriate VAR model. For the stationarity of the series, the difference was taken and continued. In the selected appropriate var model (2 lagged model), there is no autocorrelation and changing variance problem and the roots are stable. Granger causality test results are as follows:

Table 7. Granger Causality Test Results

Dependent Variable	**Independent Variable**	**Chi-sq**	**Direction of the Relationship**
Δlngdp	Δlnec	7,21** (0,03)	E→Y
Δlnec	Δlngdp	0,55 (0,76)	

Notes: Values in parentheses denote probability values and *, ** and *** denote crit, values at 1%, 5% and 10% significance levels, respectively,

Based on the results of the Granger Causality Test, there is evidence of a Granger causality relationship from EC to growth at a significance level of 5%, while no such relationship is observed from growth to EC. Considering both results together, it can be concluded that the growth hypothesis holds true with the available data for the period 1970-2019 in Türkiye.

5. CONCLUSION

The concept of energy is approached from various perspectives within economic theories. In neoclassical theory, energy has been considered an intermediate good and not directly treated as a primary factor of production. The rationale for not regarding it as a factor of production stems from the belief that economic growth and technological advancements would preempt the possibility of resource depletion. In essence, they assert that human-made capital can infinitely substitute for natural capital. Within the framework of endogenous growth theory, energy is also treated as an intermediate good, yet the theory acknowledges that the substitutability of energy is limited. It emphasizes that technological advancements should lower energy costs, making energy utilization more efficient. The theory suggests that growth could be constrained without adequate energy, underscoring its paramount significance for sustainable growth. Contrastingly, the biophysical theory provides a distinct perspective, asserting that energy plays a vital role in economic growth, even pinpointing the pivotal role of energy in driving the Industrial Revolution. From the viewpoint of biophysical economists, such as Roegen, energy is deemed a fundamental production factor. Roegen argues that since energy resources are non-renewable, growth may decelerate and even halt as these resources are depleted. This study investigated the relationship between EC and EG from the perspective of biophysical theory. The biophysical theory, which considers energy as a fundamental production factor, posits that the impact of energy on the economy is more direct. In models formulated within this theory, the relationship between EC and EG has been directly examined through two variables. Total final electricity consumption has been used for the EC variable, and real GDP for economic growth. Taking structural breaks into account, the Gregory-Hansen cointegration result indicates that at a 5% significance level, a cointegration relationship is identified when the dependent variable is growth. The test determines the year 2010 as the breakpoint. To estimate the long-term and error correction coefficients, DOLS, FMOLS, and CCR estimators were utilized (with the breakpoint from the Gregory-Hansen test included as a dummy variable in the models). According to DOLS, FMOLS, and CCR results, the statistically significant long-term coefficient of EC on EG implies a positive relationship in the long run. A 1% increase in EC in Türkiye corresponds to an increase of 0,37%, 0,72%, and 0,69% in real GDP, respectively. The dummy variable employed in the DOLS, FMOLS, and CCR cointegration analyses is statistically significant. The identified year of 2010 through the Gregory-Hansen cointegration method points to significant changes in the Turkish economy. When considering the events of 2010, the global financial crisis that deeply impacted the world economy, notably the Mortgage Crisis occurring between 2007 and 2008, comes to the forefront. The repercussions of this multinational financial crisis were felt between 2007 and 2010. The 2010 structural break marks a key turning point for Türkiye's economy, reflecting significant shifts in energy policies and growth dynamics. Post-2010, Türkiye accelerated investments in energy security, renewables, and efficiency, coinciding with recovery from the global financial crisis and a shift toward domestic-demand-driven growth. This break indicates a stronger, evolving link between energy consumption and economic growth, underscoring the importance of accounting for structural changes in economic analysis. Depended on the error correction model results for FMOLS and CCR, according to the FMOLS estimator, a short-term deviation between the variables that move together in the long-run is eliminated after 3,33 (1/0,30) years and reaches the long-run equilibrium, while according to the CCR estimator, a short-term deviation between the variables that move together in the long-run is eliminated after 1,44 (1/0,69) years and reaches the long-run equilibrium. In addition, according to the results of the Granger Causality Test, there is a Granger Causality relationship from EC to growth at 5% significance level, while there is no Granger Causality relationship from growth to EC. When the two results are evaluated together, it is concluded that the growth hypothesis is valid with the available data for the period 1970-2019 in Türkiye. The findings of this study reveal that the growth hypothesis is valid in Türkiye. In other words, EC is the Granger cause of EG and there is a unidirectional and positive relationship between them. This result indicates that an increase in EG does not drive energy consumption; on the contrary, EC drives EG. This finding is in line with the growth hypothesis put forward in studies such as Bowden and Payne (2009), Ang (2007), Tsani (2010), Ho and Siu (2007), Park and Yoo (2014) and Gupta and Sahu (2009), which find that EC determines EG through Granger causality. Moreover, while the study by Lise and Van Montfort (2007) found a causality from EG to EC in Türkiye, the fact that this study found a causality from EC to EG can be explained by the updated data set, the consideration of structural breaks and the use of the biophysical theoretical framework. On the other hand, this finding, which contradicts studies such as Zou and Chau (2006) that suggest that there is no causality between EC and EG, suggests that EC may play a determinant role on EG in highly energy-dependent economies such as Türkiye, and emphasizes that causality relationships may differ on the basis of country-specificity. One of the most important limitations of this study is that the analysis period is limited to the years 1970-2019. In particular, the fact that the effects of the COVID-19 pandemic that emerged after 2019 on economic growth and energy consumption have not yet been fully evaluated restricts the study from reflecting current dynamics. In addition, the difficulties experienced in obtaining up-to-date, consistent and comparable energy consumption data during the pandemic process caused the analysis period to end in 2019. In this context, studies to be conducted with more up-to-date data sets that include the effects of the pandemic and subsequent processes in the future will reveal the relationship between EC and EG in Türkiye in a more comprehensive and up-to-date manner. In conclusion, when the results are collectively evaluated, it is observed that EC is the Granger cause of growth and validates the growth hypothesis model established for Türkiye. These findings highlight the significant impact of the relationship between EC and EG in the case of Türkiye. Overall, these results indicate that energy incentive policies that policymakers can implement would serve as a supportive factor for economic growth. Policies aimed at increasing energy efficiency, measures promoting the use of renewable energy sources, and initiatives facilitating energy savings can promote economic growth and support sustainable development. Therefore, designing and implementing energy policies in line with economic growth objectives will be an important strategy.

DECLARATION OF THE AUTHORS

Approval of ethical committee: All procedures performed in studies comply with the ethical standards of comparable institutional and/or national research committees.

Declaration of Contribution Rate: The authors have equal contributions.

Declaration of Support and Thanksgiving: No support is taken from any institution or organization.

Declaration of Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

Alam, M. S. (2006). Economic growth with energy. *Munich Personal RePEc Archive 2006; Working Paper*, 1260, 1-25.

Ang, J. B. (2007). CO2 emissions, energy consumption, and output in France. *Energy Policy*, *35*(10), 4772-4778.

Ayres, R., & Bergh, J. C. (2005). A theory of economic growth with material/energy resources and dematerialization: Interaction of three growth mechanisms. *Ecological Economics*, *55*(1), 96-118.

Bowden, N., & Payne, J. E. (2009). The causal relationship between US energy consumption and real output: a disaggregated analysis. *Journal of Policy Modeling*, *31*(2), 180-188.

Cheng, B. S. & Andrews, D. R. (1998). Energy and economic activity in the United States: Evidence from 1900 to 1945. *Energy Sources*, *20*(1), 35-44.

Cheng, B. S. (1995). An investigation of cointegration and causality between energy consumption and economic growth. *The Journal of Energy and Development*, *21*(1), 73-84.

Ciarreta, A., & Zárraga, A. (2009). Electricity consumption and economic growth: Evidence from Spain. *Applied Economics Letters, 17*(14), 1417-1421.

Dam, M. M., & Sarkodie, S. A. (2023). Renewable energy consumption, real income, trade openness, and inverted load capacity factor nexus in Turkiye: Revisiting the EKC hypothesis with environmental sustainability. *Sustainable Horizons*, 8, 100063.

Farahani Yazdan, G., & Hossein, S. S. M. (2012). Causality between oil consumption and economic growth in Iran: An ARDL testing approach. *Asian Economic and Financial Review*, *2*(6), 678.

Ghosh, S. (2002). Electricity consumption and economic growth in India. *Energy policy*, *30*(2), 125-129.

Granger, C. W. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica*, *37*(3), 424-438.

Gregory, A. W., & Hansen, B. E. (1996). Residual-based tests for cointegration in models with regime shifts. *Journal of Econometrics*, *70*(1), 99-126.

Gupta, G., & Sahu, N. C. (2009). Causality between electricity consumption & economic growth: Empirical evidence from India. *Munich Personal RePEc Archive 2009 Working Paper,* 22942.

Gurgul, H., & Lach, Ł. (2012). The electricity consumption versus economic growth of the Polish economy. *Energy Economics*, *34*(2), 500-510.

Güneş, İ. ve Erol, E. D. (2024). Türkiye'de enerji ithalatı, ekonomik büyüme ve cari açık ilişkisi. *The Journal of Academic Social Science*, *45*(45), 340-352.

Hall, C. A., & Klitgaard, K. A. (2006). The need for a new biophysical-based paradigm in economics for the second half of the age of oil. *International Journal of Transdisciplinary Research*, 1.

Han, A. (2022). E7 ülkelerinde yenilenebilir enerji tüketimi ve ekonomik büyüme ilişkisinin incelenmesi. *Uluslararası Yönetim İktisat ve İşletme Dergisi*, *18*(3), 797-814.

Hansen, B. E., & P. C. B. Phillips (1990). Estimation and inference in models of cointegration: A Simulation Study. *Advances in Econometrics*, 8, 225-248.

Ho, C. Y., & Siu, K. W. (2007). A dynamic equilibrium of electricity consumption and GDP in Hong Kong: an empirical investigation. *Energy Policy*, *35*(4), 2507-2513.

Hussen, A. M. (2004). *Princibles of environmental economics.* Newyork, London: Routledge, 251.

Ikegami, M., & Wang, Z. (2016). The long-run causal relationship between electricity consumption and real GDP: Evidence from Japan and Germany. *Journal of Policy Modeling*, *38*(5), 767-784.

Kennedy, C. (2022). The intersection of biophysical economics and political economy. *Ecological Economics,* 192, 107272.

Kraft A., & Kraft J. (1978). On the relationship between energy and GNP. *The Journal of Energy and Development*, *3*(2), 401–403.

Kyophilavong, P., Shahbaz, M., Anwar, S., & Masood, S. (2015). The energy-growth nexus in Thailand: Does trade openness boost up energy consumption?. *Renewable and Sustainable Energy Reviews*, 46, 265-274.

Lise, W., & Van Montfort, K. (2007). Energy consumption and GDP in Türkiye: Is there a co-integration relationship?. *Energy Economics*, *29*(6), 1166-1178.

Lu, W. C. (2017). Electricity Consumption and economic growth: evidence from 17 Taiwanese industries. *Sustainability*, *9*(1), 50.

Mehmood, B., Feliceo, A., & Shahid, A. (2014). What causes what? aviation demand and economic growth in Romania: Cointegration estimation and causality analysis. *Romanian Economic and Business Review*, *9*(1), 21-34.

Narayan, P. K., & Smyth, R. (2005). Electricity consumption, employment and real ıncome in australia evidence from multivariate granger causality tests. *Energy Policy*, *33*(9), 1109-1116.

Ockwell, D. G. (2008). Energy and economic growth: Grounding our understanding in physical reality. *Energy Policy,* (36), 4601.

Örnek, İ. ve Kabak, S. (2023). Yenilenebilir enerji tüketimi ve ekonomik büyüme arasındaki ilişki: Türkiye üzerine bir inceleme. *Artuklu Kaime Uluslararası İktisadi ve İdari Araştırmalar Dergisi*, *6*(2), 87-108.

Park, S. Y., & Yoo, S. H. (2014). The dynamics of oil consumption and economic growth İn Malaysia. *Energy Policy*, 66, 218-223.

Park, J. Y. (1992). Canonical cointegrating regressions. *Econometrica*, *60*(1), 119-143.

Perron, P. (1989). The great crash, the oil price shock, and the unit root hypothesis. *Econometrica, 57*(6), 1361-1401.

Roegen, N. G. (1976). *Energy and economic myths: Institutional and analytical economic essays*. Pergamon Press.

Salahuddin, M., & Alam, K. (2015). Internet usage, electricity consumption and economic growth in Australia: A time series evidence. *Telematics and Informatics*, *32*(4), 862-878.

Shiu, A., and Lam, P.-L. (2004). Electricity consumption and economic growth in China. *Energy Policy*, *32*(1), 47-54.

Stern, D. I. (1993). Energy and economic growth in the USA. *Energy Economics*, *15*(2), 137–150.

Stern, D. I. (2000). A multivariate cointegration analysis of the role of energy in the us macroeconomy. *Energy Economics*, *22*(2), 267-283.

Stern, D. I. (2010). The Rol of Energy in Economic Growth. *The Australian National University, CCEP Working paper, 3*(10), 9.

Stock, J. H., & Watson, M. W. (1993). A simple estimator of cointegrating vectors in higher order integrated systems. *Econometrica*, *61*(4), 783-820.

Tang, C. F., Shahbaz, M., & Arouri, M. (2013). Re-Investigating the electricity consumption and economic growth nexus in Portugal. *Energy Policy*, *62*, 1515-1524.

Tartari, P. N. (2023). The BRICS and the global political economy: Challenging classical economic approaches and insights fort the furture. *Brazilian Journal of Law & International Relations*, *4*(42), 277-290.

Tosunoğlu, M., & Uçal, H. (2025). The relationship between energy consumption and economic growth: cointegration and causality approaches. *Pamukkale Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, (67), 177-193.

Tsani, S. Z. (2010). Energy consumption and economic growth: A causality analysis for Greece. *Energy Economics*, *32*(3), 582-590.

Vecchione, G. (2011). Economic growth, electricity consumption and foreign dependence in Italy between 1963–2007. *Energy Sources, Part B: Economics, Planning, and Policy*, *6*(3), 304-313.

Yang, H. Y. (2000). A note on the causal relationship between energy and GDP in Taiwan. *Energy Economics*, *22*(3), 309-317.

Yoo, S.-H. (2005). Electricity consumption and economic growth: evidence from Korea. *Energy Policy*, *33*(12), 1627-1632.

Yu, E. S. H., & Jin, J. C. (1992). Cointegration consumption, tests of energy income, and employment. *Resources and Energy*, *14*(3), 259-266.

Zivot, E., & Andrews, D. W. K. (1992). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of Business & Economic Statistics*, *10*(3), 251–270.

Zou, G., & Chau, K. W. (2006). Short-and Long-Run Effects between Oil Consumption and Economic Growth in China. *Energy Policy*, *34*(18), 3644-3655.

World Development Indicators (2020, May 20). *Popular Indicators.* https://databank.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG/1ff4a498/Popular-Indicators

World Energy Council Turkiye (2021, January 22). *Türkiye Enerji Denge Tabloları*. https://www.dunyaenerji.org.tr/turkiye-enerji-denge-tablolari/.