Pamukkale Üniversitesi

Sosyal Bilimler Enstitüsü Dergisi

Pamukkale University Journal of Social Sciences Institute

ISSN 1308-2922 E-ISSN 2147-6985

Article Info/Makale Bilgisi
√Received/Geliş: 03.04.2024 **√Accepted/Kabul:** 29.01.2025
DOI:10.30794/pausbed.1464319
Research Article/Araştırma Makalesi

Tosunoğlu, M., Uçal, H. (2025). "The Relationship Between Energy Consumption and Economic Growth: Cointegration and Causality Approaches", *Pamukkale University Journal of Social Sciences Institute*, issue 67, pp. 177-193.

THE RELATIONSHIP BETWEEN ENERGY CONSUMPTION AND ECONOMIC GROWTH: COINTEGRATION AND CAUSALITY APPROACHES

Mahir TOSUNOĞLU[*], Halil UÇAL[**]

Abstract

With its increasing population and growing economy, Türkiye's demand for energy consumption is increasing rapidly. This study contributes to the energy-economic growth literature by examining the relationship between real gross domestic product and electricity consumption by adding the determinants of the production function in Türkiye, such as labor and capital, and using annual data for the period 1988-2019. Autoregressive Distributed Lag Bounds Test, Error Correction Mechanism and Granger Causality Test were used to evaluate the relationship between energy consumption (EC), economic growth (EG), labor and capital in the long and short term. The results show that there is a cointegration relationship between EG and EC. The error correction coefficient is significant and a short-term deviation recovers within a period of 2.5 years and reaches the long-term balance. Moreover, a causal relationship from EC to EG was determined. This reveals that EC plays an important role in Türkiye's EG paradigm and supports the growth hypothesis. It is suggested that policies should prioritize increasing energy investments in Türkiye in order to promote stable economic growth.

Keywords: *Economic Growth, Energy Consumption, ARDL, ECM, Granger Causality.*

ENERJİ TÜKETİMİ VE EKONOMİK BÜYÜME ARASINDAKİ İLİŞKİ: EŞ BÜTÜNLEŞME VE NEDENSELLİK YAKLAŞIMLARI

Öz

Artan nüfus ve büyüyen ekonomisiyle Türkiye'nin enerji tüketimine olan talebi hızla artmaktadır. Bu çalışma, reel gayri safi yurtiçi hasıla ile elektrik tüketimi arasındaki ilişkiyi emek ve sermaye gibi Türkiye'deki üretim fonksiyonunun belirleyicilerini ekleyerek ve 1988-2019 döneminin yıllık verilerini kullanarak inceleyerek, enerji-ekonomik büyüme literatürüne katkıda bulunmaktır. Uzun ve kısa vadede enerji tüketimi (EC), ekonomik büyüme (EG), emek ve sermaye arasındaki ilişkiyi değerlendirmek için Gecikmesi Dağıtılmış Otoregresif Sınır Testi, Hata Düzeltme Mekanizması ve Granger-Nedensellik Testi kullanılmıştır. Sonuçlar, EG ile EC arasında eşbütünleşme ilişkisi olduğu göstermektedir. Hata düzeltme katsayısı anlamlıdır ve kısa vadeli bir sapma 2,5 yıllık bir süre içinde düzelerek uzun vadeli dengeye kavuşur. EC'den EG'ye doğru bir nedensellik ilişkisi tespit edilmiştir. Bu, Türkiye'nin EG paradigmasında EC'nin önemli bir rol oynadığını ve büyüme hipotezini desteklediğini ortaya koymaktadır. İstikrarlı ekonomik büyümeyi teşvik etmek için politikaların Türkiye'de artan enerji yatırımlarını önceliklendirmesi önerilmektedir.

Anahtar kelimeler: *Ekonomik Büyüme, Enerji Tüketimi, ARDL, ECM, Granger Nedensellik.*

*PhD Student, Ege University, Faculty of Economics and Administrative Sciences, Department of Economics, İZMİR.
e-mail: mtosunoglu00@gmail.com, (https://orcid.org/0000-0002-9941-0151)
* Asst. Prof. Dr., Pamukkale University, Faculty of Economics and Administrative Sciences, Department of Economics, DENİZLİ
e-mail: hucal@pau.edu.tr , (https://orcid.org/0000-0002-1475-2962)

1.INTRODUCTION

After the 1970s, the thesis of the infinity of energy resources and ease of transportation, which is common in the world, has disappeared. This crisis in the 1970s led to a major economic crisis in the world. During this period, many countries experienced economic recession. After this crisis, the concepts of energy and economic growth have become more common.

When we look at the place of the concept of energy in the economy, it is seen that it is evaluated within natural resources. When the concept of energy goes to its origin in terms of economy, it is seen that this issue has been coming 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 emphasized the importance of soil and water and thought that wealth would be provided by 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 was with the Physiocrats (Ayres et al., 2013).

Until the 1970s, when the oil crises were experienced, the concept of energy was not given much importance except for Jevons and Hotelling. When the concept of energy and the concepts of economic growth are examined together; It has been seen that classical growth theories focus on labor and capital and do not dwell on energy resources as intermediate goods. To provide further clarification, delving into the rationale behind the non-classification of energy as a production factor, it stems from the notion that economic expansion and technological advancements will thwart the potential exhaustion of ecological reserves. This assumption posits that the costs associated with natural resources will be effectively internalized through pricing mechanisms, consequently remedying market deficiencies, and perpetually substituting naturally occurring capital with human-made counterparts (Yaprakli, 2013; Yaprakli and Yurttancikmaz, 2012).

When we look at endogenous growth models, it can be said that they are complementary to neoclassical theory. They accepted energy as an intermediate good, but differently, they recognised that growth without energy may be limited, that technological developments should reduce energy costs and make energy efficiently available (Cheng ve Andrews, 1998; Yaprakli, 2013). Additionally, they acknowledge the finite nature of the substitutive correlation involving energy. They highlight the paramount role that energy plays in ensuring sustainable economic growth. This underscores the imperative for governmental intervention. Moreover, they contend that advancements in technology and robust research and development endeavors ought to drive enhanced energy efficiency and consequent reductions in energy expenditures (Zon and Yetkiner, 2005).

As the 1980s drew to a close, the emergence of biophysical economics became prominent, marked by its interdisciplinary and environmentally conscious research approach. Notably, these scholars stress the pivotal role of energy in driving economic growth, even tracing its critical impact back to the industrial revolution. Among these thinkers, Roegen, a notable biophysical economist, underscored energy's foundational status as a production factor. He asserted that when energy resources become depleted, the pace of growth could decelerate or cease entirely due to its non-renewable nature. Furthermore, the inputs such as labor and capital, integral to the economy, stem from the mobility of energy—essentially, its flow. Consequently, it was postulated that energy consumption significantly influences the productivity of both capital and labor, directly contributing to the production process (Alam, 2006; Stern, 2011).

Energy consumption is a critical determinant of economic growth, particularly for Türkiye's sustainable development goals. According to growth models, energy serves as an indispensable input that supports primary production factors like labor and capital in production processes. In developing countries like Türkiye, increases in energy consumption are directly linked to the expansion of industrial, transportation, and service sectors. Furthermore, energy consumption reflects the intensity of economic activities, and enhancing energy efficiency or increasing the use of renewable energy sources can bolster economic growth. Studies generally find a positive relationship between energy consumption and economic growth, though the dynamics of this relationship may vary depending on the model and period analyzed (Kraft and Kraft, 1978; Soytas and Sari, 2003).

This article examines the complex relationship between energy consumption and economic growth in Türkiye for the period 1988-2019. In this model, electricity consumption is used for energy consumption and real GDP is used for economic growth. In addition, a research on a growth model is developed by including labor and capital variables in the model. This model contributes to the energy economics literature by being examined with Autoregressive Distributed Lag Bounds Test, Error Correction Mechanism and Granger-Causality Test methods. Unlike the existing literature, the examination is carried out on a growth model by including labor and capital variables in the model.

The paper consists of four separate sections. Section 1 presents a review of the relevant literature. Section 2 outlines the methodology used in the estimation process. Section 3 presents in detail the model and its theoretical structure, the data used for the variables, and the empirical test results and interpretations. Finally, Section 4 presents the conclusions and policy recommendations.

2. EMPIRICAL LITERATURE REVIEW

Over the years, various efforts have been made to unravel the patterns and causal relationships between energy and economic growth under different supporting models. The energy-growth nexus focuses on the impact of energy as a production factor within a country's economy. This relationship examines how energy consumption influences economic output and, conversely, how economic growth can affect energy needs. Understanding these dynamics is essential for developing effective policies that promote sustainable growth while ensuring energy security (Ekonomou and Halkos, 2023).

The hypotheses regarding the relationship between energy consumption (EC) and economic growth (EG) are examined under four main categories: the growth hypothesis, the conservation hypothesis, the neutrality hypothesis, and the feedback hypothesis. The growth hypothesis posits a unidirectional causality from EC to EG, suggesting that increases in EC lead to growth in the economy, and conversely, decreases in EC result in a decline in EG. The conservation hypothesis, on the other hand, suggests a unidirectional causality from EG to EC. According to this hypothesis, an increase in a country's EG leads to a corresponding increase in EC. It implies that energy-saving policies implemented by countries do not adversely affect economic output. The neutrality hypothesis, also known as the indifference hypothesis, asserts that there is no causality between EC and EG. This means that neither expansionary nor restrictive energy policies impact economic output since there is no correlation between the two variables. Instead, it suggests that other factors are influencing EG. Finally, the feedback hypothesis proposes a bidirectional causality between EC and EG. This means that if either variable is stimulated, both economic output and energy consumption will increase. Conversely, if there are restrictions in one of the variables, it will negatively affect the other (Menegaki and Tugcu, 2016).

When examining the general characteristics of the literature on EC and EG, a common focal point emerges: researchers primarily aim to explore the persistent correlations and causal connections between these variables. It is evident that time series test is frequently employed in the literature to investigate the relationship between energy consumption (EC) and economic growth (EG). Many of these studies reach a consensus on the existence of long-term relationships between the variables. However, a detailed examination of causality analyses reveals significant regional differences in the results. The empirical literature table is as follows:

Table 1: Empirical Literature Summary

Author(s)	Variables	Country and Period	Methodology	Findings	Hypothesis
Yu and Jin (1992)	EC, GDP	USA 1974 - 1990	Cointegration Test, Granger Casuality Test	E→ Y	Growth Hypothesis
Stern (1993)	EC, GDP	USA 1947-1990	Granger Casuality Test, Multivariate VAR Test	E→ Y	Growth Hypothesis
Cheng (1995)	EC, GDP	USA 1947-1990	Co-integration Test, Granger Casuality Test	Y→E	Conservation Hypothesis

Stern (2000)	EC, GDP	USA 1948-1994	Co-integration Test, Granger Casuality Test	E↔ Y	Feedback Hypothesis
Yang (2000)	EC, GDP	Taiwan 1954-1997	Granger Casuality Test	E↔ Y	Feedback Hypothesis
Ghosh (2002)	per capita ELC, per capita real GDP	Indian 1950-1997	Johansen Co-integration Test, Granger Casuality Test	The variables are cointegrated. Y→ E	Conservation Hypothesis
Soytas and Sari (2003)	EC, GDP	Türkiye 1950-1992	Granger Casuality Test	E→ Y	Growth Hypothesis
Shiu and Lam (2004)	ELC, real GDP	Chinese 1971-2000	Johansen Co-integration Test, Granger Casuality Test, ECM	The variables are cointegrated. E→ Y	Growth Hypothesis
Altinay and Karagol (2004)	EC, GDP	Türkiye 1950-2000	Granger Casuality Test (Hsiao version)	E ↛ Y	Neutrality Hypothesis
Altınay and Karagol (2005)	ELC, real GDP	Türkiye 1950-2000	VAR Test, Dolado–Lütkepohl Casuality Test, Granger Casuality Test	E→ Y	Growth Hypothesis
Narayan and Smyth (2005)	per capita ELC, Emp, per capita real GDP	Australia 1966-1999	Co-integration Test, Granger Casuality Test	Variables are cointegrated. Y→ E Y→ Emp	Conservation Hypothesis
Zou and Chau (2006)	OC, EG	Chinese 1953-2002	Co-integration Test, Granger Casuality Test	Oil consumption and GDP are cointegrated. E ↛ Y	Neutrality Hypothesis
Ho and Siu (2007)	ELC, real GDP	Hong Kong 1966 - 2002	Co-integration Test, Granger Casuality Test and VECM	Variables are cointegrated. E→ Y	Growth Hypothesis
Ang (2007)	EC, CO_2, GNP	France 1960-2000	VECM, Co-integration Test	Variables are cointegrated. E→ Y	Growth Hypothesis
Jobert and Karanfil (2007)	EC, GDP, per capita EC, per capita GDP	Türkiye 1960-2003	Granger Casuality Test	E→ Y	Growth Hypothesis
Lise and Van Montfort (2007)	EC, GDP	Türkiye 1970-2003	Co-integration Test, Granger Casuality Test	Energy Consumption and GDP are co-integrated. Y→ E	Conservation Hypothesis
Antunano and Alonso (2007)	ELC, real GDP	Spain 1971-2005	Co-integration Test, Granger Casuality Test	Y→ E	Conservation Hypothesis
Bowden and Payne (2009)	EC, real GDP	USA 1949 - 2006	Toda-Yamamoto, Granger Casuality Test	E→ Y	Growth Hypothesis
Gupta and Sahu (2009)	ELC, EG	India 1960-2006	Granger Casuality Test	E→ Y	Growth Hypothesis
Vecchione (2010)	ELC real GDP	Italy 1963-2007	VECM, Granger Casuality Test	Y→ E	Conservation Hypothesis
Gurgul and Lach (2012)	ELC, real GDP	Poland 2010-2009 (quarterly)	Johansen Co-integration Test, ECM, Granger Casuality Test	The variables are cointegrated. E↔ Y	Feedback Hypothesis
Shahbaz, Khan and Tahir (2013)	EC, FD, Cap, Exp, Imp, IT, GDP	Chinese 1971- 2011	Johansen Co-integration Test, Granger Casuality Test, ARDL Bounds Test, VECM	The variables are cointegrated. E→ Y E↔ IT E↔ FD Y↔ FD Y↔ IT	Growth Hypothesis
Tang, Shahbaz and Arouri (2013)	per capita ELC, per capita real GDP	Portugal 1974-2009	ARDL Bounds Test, VECM, Co-integration Test, Granger Casuality Test	The variables are cointegrated. E↔ Y	Feedback Hypothesis

Park and Yoo (2014)	OC, real GDP	Malaysia 1965 - 2011	Co-integration Test, ECM, Granger Casuality Test	Oil consumption and real GDP are cointegrated. E↔ Y	Feedback Hypothesis
Ucak and Usupbeyli (2015)	OC, real GDP	Türkiye 1971-2013	Johansen Co-integration Test, Granger Causality Test	OC and real GDP are not cointegrated. E ↮ Y	Neutrality Hypothesis
Ikegami and Wang (2016)	ELC, real GDP	Germany and Japan 1996:04-2015:02	ARDL Bounds Test, Granger Casuality Test	ELC and real GDP are co-integrated. For Germany: Y→ E For Japan: E→ Y	For Germany: Conservation Hypothesis For Japan: Growth Hypothesis
Lu (2017)	IEC, real GDP (Industry)	Taiwan 1998-2014	Co-integration Test and Granger Causality Test	The variables are cointegrated. E↔ Y	Feedback Hypothesis
Bulut et al. (2021)	ELC, EG	Türkiye 2005-2020	Non-ARDL Bounds Test and Toda-Yamamoto Casuality Test	The variables are cointegrated. E→ Y	Growth Hypothesis
Uslu (2022)	EC, FD, real GDP	Türkiye 1960-2019	Gregory-Hansen Test and Maki Test	The variables are cointegrated. Y→ E	Conservation Hypothesis
Kizilkaya (2023)	EC, EG	Türkiye 1965-2021	Bayer-Hanck Co-integration Test	The variables are cointegrated. E→ Y	Growth Hypothesis
Ozgun (2024)	EC, LE, EG	Türkiye 1990-2022	ARDL Bounds Test	The variables are cointegrated. E→ Y	Growth Hypothesis

Relationship Direction: "→" The direction of the one-sided relationship, "↔" bilateral relationship and "↮" It represents unrelatedness.

Abbreviations: Cap: Capital, CH: Conservation Hypothesis, CO_2: Carbondiocixde, DEF: Deficit, EC: Energy Consuption, ECM: Error Correction Model, EG: Economic Growth, ELC: Electricity Consumption, Exp: Export, LE: Life Expectation, FD: Financial Development, FH: Feedback Hypothesis, FTD: Foreign Trade Deficit, Imp: Import, GDP: Gross Domestic Product, GH: Growth Hypothesis, IEC: Industrial Electricity Consumption, GNP: Gross National Product, IT: International Trade, NH: Neutrality Hypothesis, OC: Oil Consumption, VECM: Vector Error Correction Model

3. METHODOLOGY

In this section, the methods used in the study are given in detail. These are Augmented-Dickey&Fuller and Phillips&Perron unit root tests, Autoregressive Distributed Lag Bound test, Error-Correction Mechanism and Granger Causality test.

3.1. Augmented-Dickey&Fuller and Phillips&Perron Unit Root Tests

In time series analyses, using non-stationary variables can lead to spurious results, meaning the regression outcomes may not accurately reflect the true relationship between the variables. Therefore, before conducting statistical analyses, it is crucial to first determine the stationarity of all variables involved in the model. Stationarity test is conducted using unit root tests (Gujarati, 2004). In this study, the Augmented Dickey-Fuller (ADF) test developed by Dickey and Fuller (1981) and the Phillips-Perron (PP) test developed by Phillips and Perron (1988) were applied.

The ADF unit root test is examined under three different models. To address the issue of autocorrelation, the lagged values of the dependent variable are included in the system. The number of lags is determined based on information criteria. The ADF unit root test addresses autocorrelation parametrically (Dickey and Fuller, 1981). However, in this study, due to the structure of the data, only two models were used: the model with a constant term and the model with both a constant term and a trend. The models for the ADF unit root test are as follows:

Model without constatnt term and without trend: $\Delta\gamma_t = \delta\gamma_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta\gamma_{t-i} + \varepsilon_t$ (1)

The constant term model: $\Delta\gamma_t = \beta_0 + \delta\gamma_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta\gamma_{t-i} + \varepsilon_t$ (2)

Model with constant term and trend: $\Delta\gamma_t = \beta_0 + \beta_1 t + \delta\gamma_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta\gamma_{t-i} + \varepsilon_t$ (3)

Δy_t in the model refers to the first difference of the variable whose stationarity is tested, t trend variable, Δy_{t-i} lagged difference term. The autocorrelation problem is solved by adding a lagged difference term to the model to ensure that the error term is sequentially independent.

The Phillips-Perron (PP) test is another widely used method for determining the presence of a unit root. In the PP test, certain non-parametric adjustments are required to calculate the test statistic. As a result, autocorrelation does not affect the asymptotic distribution of the test statistic. The PP test is considered more robust than the ADF test and shares the same asymptotic distribution as the ADF unit root test (Phillips and Perron, 1988).

The hypotheses for the ADF and PP unit root tests are similar. The null hypothesis represents a unit root process, while the alternative hypothesis indicates a stationary process. If the null hypothesis is rejected, the series is considered stationary; if it is not rejected, the series is deemed to contain a unit root. The hypotheses for the unit root tests are as follows:

$H_0: \delta = 0$ (Unit root process) $H_1: \delta < 0$ (No unit root process) (4)

The Phillips-Perron test differs from the Augmented Dickey-Fuller (ADF) test in several ways. While the ADF test is a parametric test, the Phillips-Perron test is based on a non-parametric approach. Additionally, unlike the ADF test, the Phillips-Perron test does not require specifying a lag length, and it is robust to heteroskedasticity in the error terms. This robustness is one of the key strengths that makes the Phillips-Perron test more powerful than the ADF test (Phillips and Perron, 1988).

3.2. Autoregressive Distributed Lag (ARDL) Bound Test

Economic time series often have a non-stationary (unit-root) process (Johansen and Jesulius, 1990). Analyses conducted with time series with unit root process cause spurious regressions (Granger and Newbold, 1974). Consequently, differencing is implemented to establish stationarity. Nonetheless, this procedure entails the potential loss of temporal information within the time-series and could potentially disrupt the preexisting association between the series (Tarı and Yıldırım, 2009). Therefore, co-integration analyses are conducted, offering insight into the possibility that non-stationary series at their original levels could potentially exhibit a stationary amalgamation. This statistical determination is facilitated by approaches such as those outlined by Eriçok and Yılancı (2013).

Upon scrutinizing cointegration analyses, certain characteristics of the ARDL bounds testing method emerge, setting it apart from alternative cointegration approaches. The distinctive advantage of the ARDL bounds test method lies in its applicability regardless of whether the variables under examination are characterized as I(0) or I(1) (Pesaran et al., 2001). Hence, in the context of the ARDL bounds test methodology, it may not be obligatory to ascertain the integration levels of variables in advance (Narayan and Narayan, 2005).

Compared to the Engle-Granger method, the ARDL bounds testing method boasts superior statistical properties, attributed to its utilization of an unrestricted error correction model (UECM) (Narayan and Narayan, 2005). This distinctive attribute further solidifies the ARDL bounds testing method's position as an advantageous analytical approach.

Additionally, a noteworthy attribute is its adaptability to investigations featuring limited sample sizes. Extensive Monte Carlo simulations have substantiated the superiority of the bounds test over the Engle-Granger and Johansen cointegration tests, particularly in scenarios with a paucity of observations. In essence, the ARDL bounds test method yields more reliable outcomes compared to the Engle-Granger and Johansen co-integration tests when confronted with a diminished number of data points (Narayan and Smyth, 2005).

The ARDL bounds test method relies on autoregressive lagged distributed models; thus it does not inherently address the endogeneity issue of the variables. Fundamentally, the ARDL bounds test approach encompasses three key stages. The initial phase involves scrutinizing the presence of a cointegration relationship among the variables under test. Should a cointegration relationship be ascertained, the subsequent step entails constructing the long-run ARDL model for estimating long-run coefficients. Finally, the third stage encompasses estimating short-run coefficients through the employment of the error correction model (ECM) (Narayan and Smyth, 2006). The ECM equation within the ARDL framework, as adapted for the variables within this study, can be represented as follows:

$$\Delta lnGDP_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i}\Delta lnGDP_{t-i} + \sum_{i=1}^{p} \beta_{2i}\Delta lnEC_{t-i} + \sum_{i=1}^{p} \beta_{3i}\Delta lnK_{t-i} + \sum_{i=1}^{p} \beta_{4i}\Delta \mathrm{lnL}_{t-i} + \beta_5 lnGDP_{t-1} + \beta_6 lnEC_{t-1} + \beta_7 lnK_{t-1} + \beta_8 \ln L_{t-1} + \varepsilon_t \quad (5)$$

The subsequent equations introduce the notation: Δ represents the difference operator, β_0 stands for the constant term coefficient, β_{1i} - β_{4i} denote the short-run coefficients, and β_5 - β_8 represent the long-run coefficients. The variable εt pertains to the error terms, while p signifies the lag lengths applicable to both independent and dependent variables. Notably, within the bounds test methodology, the F-test's sensitivity to the lag length is noteworthy (Bahmani-Oskooee and Goswami, 2003). The determination of the optimal lag length for variables rests on information criteria such as Akaike (AIC), Schwarz (SIC), and Hannan-Quinn (HQ) (Narayan and Narayan, 2005).

Subsequent to the establishment of the lag length, the F-test is concerned with assessing the significance of the level and lagged values of both dependent and independent variables (Narayan and Narayan, 2005). In essence, this process entails scrutinizing the statistical significance of the lagged values corresponding to the level variables of both the dependent and independent variables within our model. This scrutiny serves as the main hypothesis test, evaluating the validity of the core proposition asserting the absence of a cointegrated relationship between the variables. Contextually, the fundamental hypothesis valid for our model can be expressed as follows:

$$H_0 : \beta_5 = \beta_6 = \beta_7 = \beta_8 = 0 \quad (6)$$

The F-test outcome was juxtaposed against critical values established at various levels of significance, as defined by Pesaran et al. (2001). Nevertheless, recognizing that these critical values from Pesaran et al. (2001) were formulated for larger sample sizes, Narayan (2005) derived and consolidated new values more suited for studies with constrained observations. Within this framework, should the computed F-statistic surpass the critical value, the null hypothesis positing the absence of a cointegration relationship among variables is dismissed. Conversely, if the F-statistic falls below the lower threshold of the critical value, the null hypothesis is upheld (Narayan, 2005). When the F-statistic resides within the spectrum bounded by the lower and upper thresholds, no definitive conclusion regarding cointegration can be drawn (Narayan and Narayan, 2005).

Following the confirmation of a cointegration relationship's existence, the subsequent step entails formulating the "long-run ARDL model." This endeavor serves to determine the long-run coefficients for independent variables. During this second phase, the construction of the long-run ARDL model incorporates the Akaike information criterion to identify the lag length dictating the enduring relationship between variables. The expression representing the long-run ARDL model pertinent to our study can be expressed as follows:

$$lnGDP_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} lnGDP_{t-i} + \sum_{i=1}^{p} \beta_{2i} lnEC_{t-i} + \sum_{i=1}^{p} \beta_{3i}\Delta lnK_{t-i} + \sum_{i=1}^{p} \beta_{4i}\mathrm{ln}L_{t-i} + \varepsilon_t \quad (7)$$

In the equation, β_0 refers to the long-term constant term coefficient, β_{1i} - β_{4i} refers to the long-term coefficients, p lag length and ε_t refers to the long-term error term.

3.3. Error-Correction Mechanism (ECM)

The error-correction mechanism offers a solution for addressing cointegration within a single-equation framework, particularly when the parameter estimators of interest exhibit weak exogeneity. This test is structured as an Error-Correction Mechanism (ECM) test, hinging on the Ordinary Least Squares (OLS) coefficient derived from the lagged dependent variable within an extended Autoregressive Distributed Lag (ARDL) model of estimators (Banerjee, Dolado and Mestre, 1998).

Subsequent to the estimation of long-run coefficients through the ARDL bounds test method, the process involves estimating the short-run coefficients alongside the coefficient of the error correction term by formulating an error-correction model (Narayan and Narayan, 2005). The error correction model for our particular study can be succinctly presented as follows:

$$\Delta lnGDP_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i}\Delta lnGDP_{t-i} + \sum_{i=1}^{p} \beta_{2i}\Delta lnEC_{t-i} + \sum_{i=1}^{p} \beta_{3i}\Delta lnK_{t-i} + \sum_{i=1}^{p} \beta_{4i}\Delta \ln L_{t-.i} + \beta_1 ECT_{t-1} + \varepsilon_t \quad (8)$$

In the equation above, β_{1i} - β_{4i} represents the short-run coefficients, p denotes the relative lag length, β_0 corresponds to the short-term constant term coefficient, and ε_t signifies the short-term error term. The coefficient β_1 embodies the adjustment ratio, elucidating the extent to which a short-term shock is absorbed in the long run. When ECT_{t-1} (Error correction term) is estimated between 0 and -1, the error correction process converges toward the long-term equilibrium value. An estimation between -1 and -2 implies that the error correction process reaches equilibrium while exhibiting diminished oscillations around the long-run benchmarks. A coefficient below -2 or above 0 indicates the disruption of equilibrium (Alam and Quazi, 2003).

3.4. Granger Causality Test

This examination method strives to comprehend the interplay between two time series by leveraging their historical values. As a result, the Granger causality test is derived through the utilization of the Vector Autoregressive (VAR) model, as presented below (Karaağaç and Ceylan, 2018):

$$Y_t = \alpha_0 + \sum_{i=1}^{k1} \alpha_i Y_{t-i} + \sum_{i=1}^{k2} \beta_i X_{t-i} + \varepsilon_t \quad (9)$$

$$X_t = \gamma_0 + \sum_{i=1}^{k3} \gamma_i Y_{t-i} + \sum_{i=1}^{k4} \delta_i X_{t-i} + \emptyset_t \quad (10)$$

X and Y represent two stationary time series, while α and γ represent constant terms. and represent error terms with a white noise process. In addition, k_j, j = (1,2,3,4) represents the maximum delay lengths determined by the VAR method in each time series.

In accordance with Granger (1969), when employing preceding values of X to forecast Y yields superior outcomes compared to excluding past values of X, it signifies that X serves as the Granger causal factor for Y. Simultaneously, if utilizing past values of Y to predict X proves more effective than excluding such values, then X is also identified as the Granger causal factor for Y. Furthermore, if leveraging past values of Y to forecast X yields better results than omitting past values of X, the relationship is characterized as bidirectional. Conversely, when X is not deemed the Granger causal factor for Y and, correspondingly, Y does not emerge as the Granger causal factor for X, both variables are statistically deemed independent of one another (Karaağaç and Ceylan, 2018).

4. APPLICATION

In this section, after examining the models and theoretical frameworks, the details of the relevant set used are given. The application is also included in this section.

4.1. Theoretical Framework and Model

The Cobb-Douglas production function is a widely utilized model that describes how the output in an economy is generated based on the inputs employed in the production process. It captures the relationship between the quantity of inputs, such as labor and capital, and the resulting level of output (Cottrell, 2019). The most important advantage of the functional form is that it is known with accuracy, can be applied at the level of all economies and can be used for micro predictions (Houthakker, 1955). It explicitly includes the effect of technology by integrating the A coefficient into the model (Cleveland, Schroeder and Anderson, 1989). When estimating the function in logarithmic form it is easy to obtain the production elasticities of different inputs and technologies, and the estimated coefficients can be extremely close to the refined measure of factor productivity figures (Douglas, 1976). Therefore, to determine the effect of EC on EG, the following processes were followed using the Cobb-Douglas production function in the following format:

$$Y_t = A_t K_t^{\alpha} (L_t)^{(1-\alpha)} \quad (11)$$

In this context, "Y" denotes the level of output, "K" the capital stock used for output production, "L" the labour force employed in output production and "A" a labour-increasing factor reflecting technological developments and productivity levels in the economy. Technological innovation is assumed to experience an upswing as shown in the function below:

$$A_t = A_0 EC^{\theta} \quad (12)$$

In this context, the acronym EC denotes energy consumption, while θ symbolizes the coefficient linked with energy consumption. Within the scope of the current research, the model has been extended to encompass variable A, which is influenced not only by a consistent pace of technological advancement but also by the prevailing energy consumption level within the economy (Tang, Tan, and Ozturk, 2016). With reference to the equation presented earlier, the configuration of the function is as follows:

$$Y_t = A_0 EC^{\theta} K_t^{\alpha} (L_t)^{1-\alpha} \quad (13)$$

Moreover, it can serve to elucidate the connection between EC and EG via the mechanism of technological innovation, a concept intertwined with Schumpeter's concept of "creative destruction." It is well-established that the process of "creative destruction" catalyzes the advancement of novel technologies through reinvestment in hardware and the modernization procedure. Concurrently, EC plays a pivotal role in expediting the innovation process that underpins economic growth (Tang, Tan, and Ozturk, 2016).

By applying the natural logarithm to both sides of the equation provided earlier, the equation undergoes a transformation into a linear format, depicted as follows:

$$lnY_t = A_0 + \theta lnEC_t + \alpha K_t + (1-\alpha) lnL_t \quad (14)$$

In 1992, Mankiw et al. introduced the definition of $\ln A_0$ as l , $\ln A_0 = \beta_0 + \varepsilon_t$ asserting that A_0 encapsulates not only technological advancement but also encompasses factors such as resource contributions, climate, institutions, and various other elements (Tang, Tan, & Ozturk, 2016). Here, β_0 represents the constant term and ε_t represents the error term. If we rearrange the parameters of the model; When equation 14 is rearranged using the equations: $\theta = \beta_0$, $\alpha = \beta_1$ and $(1 - \alpha) = \beta_2$, and using the $\beta_0 + \varepsilon_t$ equation, the model created is as follows:

$$lnY_t = \beta_0 + \beta_1 lnEC_t + \beta_2 K_t + \beta_3 lnL_t + \varepsilon_t \quad (15)$$

From an econometric standpoint, the fundamental structure of the empirical model well-suited for conducting econometric examination concerning the correlation between economic growth and its influencing factors is outlined as follows:

$$\ln GDP_t = \beta_0 + \beta_1 \ln EC_t + \beta_2 K_t + \beta_3 \ln L_t + \varepsilon_t \quad (16)$$

Where is the logarithm (natural), is the residual. are presumed to be normally distributed also is white noise. is real GDP, is electricity consumption, is gross-fixed capital formation, is the labor factor (employment). Finally, represents the constant term, while , and are parameters in the model.

4.2. Data

In this investigation, the logarithmic representation of real GDP, the cumulative electricity consumption (in gwh), real gross fixed capital investments (K), and employment (L) data spanning from 1988 to 2019 were employed. The real GDP, real gross fixed capital investments, and working-age population (employment) data were sourced from the World Bank platform, whereas the cumulative electricity consumption data were extracted from the balance sheets of the World Energy Council Turkish National Committee. The analytical procedures were performed using Eviews 10 software.

4.3. Application Results

The key benefit offered by the ARDL bounds test approach lies in its applicability irrespective of whether the variables under scrutiny are classified as *I*(1) or *I*(0) (Pesaran et al., 2001). Nevertheless, in order to ascertain the feasibility of the ARDL bounds test, a unit root test was conducted, particularly in light of the potential for the series to be categorized as *I*(2).

Table 2: Augmented Dickey&Fuller and Phillips&Perron Unit Root Test Results

	Augmented-DF		Phillips-Perron	
Variables	**Intercept**	**Trend & Intercept**	**Intercept**	**Trend & Intercept**
lnGDP	0.22 (0.9692)	-2.50 (0.3275)	0.56 (0.9862)	-2.53 (0.3121)
lnEC	-2.45 (0.1375)	-1.19 (0.8959)	-6.98*** (0.0000)	-0.38 (0.9837)
lnK	-0.85 (0.7896)	-2.67 (0.2549)	-0.83 (0.7973)	-2.67 (0.2549)
lnL	0.65 (0.9890)	-1.23 (0.8868)	0.60 (0.9873)	-1.33 (0.8606)
Δ lnGDP	-3.86*** (0.0069)	-3.98** (0.0221)	-6.10*** (0.0000)	-6.29*** (0.0001)
Δ lnEC	-4.36*** (0.0018)	-4.99*** (0.0019)	-4.24*** (0.0024)	-8.37*** (0.0000)
Δ lnK	-5.84*** (0.0000)	-5.74*** (0.0003)	-5.86*** (0.0000)	-5.75*** (0.0003)
Δ lnL	-5.03*** (0.0003)	-5.33*** (0.0008)	-5.10*** (0.0003)	-5.34*** (0.0008)

Notes: In establishing the count of lags for the Augmented-Dickey&Fuller test, the upper limit of lags considered is set at 2, employing the t-statistic criterion at a 10% significance level. Parenthesized figures denote probability values, while ** and *** signify critical values at 5% and 1% significance levels, respectively. In the Phillips-Perron test, "Bandwidth" is determined according to the Newey-West method and Barttlet Kernel estimator is used.

Upon reviewing the outcomes of the ADF and PP tests, it becomes evident that the logarithmically transformed variables exhibit unit roots at their initial levels. However, upon scrutinizing the values after the first differentiation, it becomes evident that the variables display stationarity, thereby confirming their *I*(1) classification. As none of the variables conform to the *I*(2) criteria, the application of the ARDL bounds test is viable.

Table 3: ARDL F-Bound of Test Results

Model	Optimal Delay Length	F-Stat	Bounds Test Critical Value		Decision
			I (0)	**I (1)**	
ln(GDP) = F (ln(EC), ln(K), ln(L))	(3, 0, 3, 1)	8.340	5.198	6.845	Cointegration

Notes: At the 1% significance level, the critical values for the *F*-statistic are established as 5.198 for the lower boundary and 6.845 for the upper boundary. As a result, the model's estimation reveals a substantial and noteworthy long-term cointegration relationship among the variables at the 1% significance level.

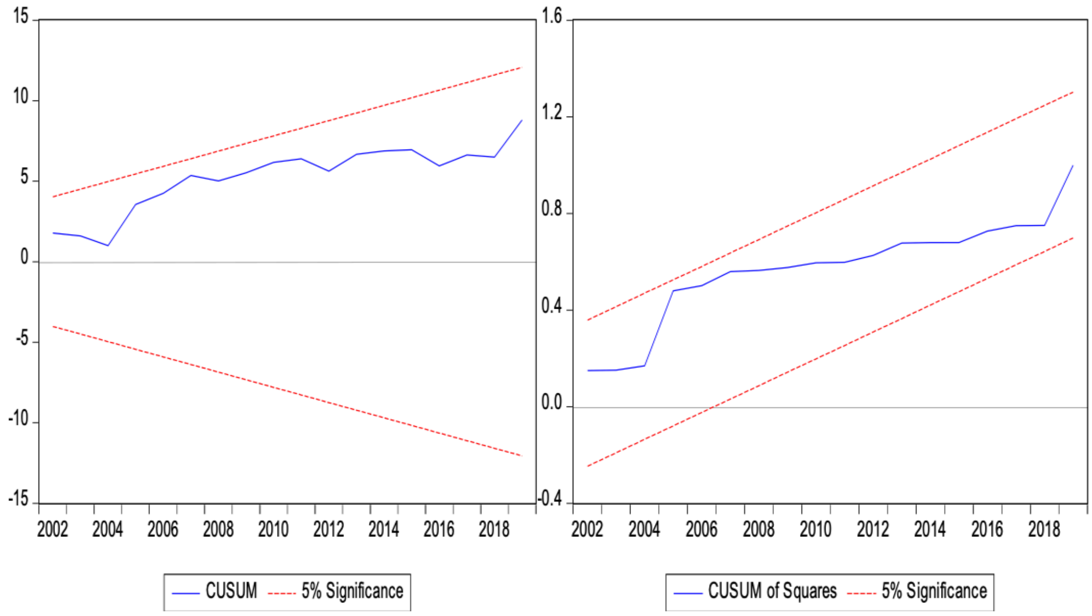
Subsequent to detecting the presence of long-term cointegration among the variables incorporated in the model through the application of the ARDL *F*-bounds test, the subsequent phases involved conducting long-term ARDL estimations. In order for the results obtained from the *F*-test to be reliable, the models must satisfy certain statistical assumptions. Diagnostic tests of these assumptions are as follows:

Table 4: ARDL Model Diagnostics Test Results

Tests	Hypotheses	Test Statistics	Results
Ramsey/Reset of Test	H_0: There is no specification error in the model (p> 0.05).	0.29 (0.60)	The null hypothesis cannot be rejected.
Breusch/Godfrey LM of Test	H_0: There is no autocorrelation between the errors of the model. (p> 0.05).	2.53 (0.11)	The null hypothesis cannot be rejected.
Breusch/Pagan-Godfrey of Test	H_0: There is no heteroscedasticity problem in the model. (p> 0.05).	0.89 (0.56)	The null hypothesis cannot be rejected.
Notes: The values in parentheses denote the probabilities associated with the *F*-statistics. The established ARDL model is (3, 0, 3, 1).			

When the results of the tests are examined, it is seen that the null hypothesis cannot be rejected. Therefore, these findings show that there is no autocorrelation problem, no heteroskedasticity problem, and no modeling error.

Lastly, the stability of parameter estimates within the series needs to be taken into account. To tackle this issue, the CUSUM CUSUM (2) tests, introduced by Brown et al. (1975), are employed. These tests serve to evaluate the stability of the estimated ARDL model and to investigate the potential occurrence of structural shifts. Upon reviewing the graphical depictions, it is discerned that, at the 5% significance level, no notable alterations in the variables' coefficients are apparent, underscoring their stability. The findings of the CUSUM (CUSUM^2) tests are elucidated as follows.



Graph 1: Results of the CUSUM or CUSUM (2) Test

After confirming the existence of a long-term cointegration relationship using the ARDL F-bound test for the variables integrated in the model, the subsequent phases involved calculating the long-term ARDL coefficients. The findings derived from the estimation of long-term ARDL coefficients are outlined as follows:

Table 5: Results of Long-Term ARDL Coefficient Estimation

Dependent Variable: Ln(GDP)	Variables	Coeff.	S.E.	*t*-stat	*p*-value
	Ln(EC)	0.20	0.05	4.49	0.0003
	Ln(K)	0.34	0.05	7.08	0.0000
	Ln(L)	0.82	0.12	6.83	0.0000

Upon reviewing the provided table, it becomes evident that when the dependent-variable is ln(GDP), the independent-variables ln(EC), ln(K), and ln(L) exhibit statistical significance at the 1% significance level. Depended on the outcomes derived from the long term ARDL test, a 1% increment in EC corresponds to a 0.20% augmentation in real GDP, while a 1% rise in gross fixed capital investment corresponds to a 0.34% increase. Additionally, a 1% upswing in the labor variable appears to result in a 0.82% enhancement in real GDP.

Table 6: Results of Short-Term ARDL and ECM

Dependent Variable: lnGDP	Variables	Coeff.	S.E.	*t*-stat	*p*-value
	Δln(GDP)(-1)	-0.38	0.14	-2.76	0.0128
	Δln(GDP)(-2)	-0.24	0.14	-1.74	0.0998
	Δln(K)	0.29	0.01	23.6	0.0000
	Δln(K)(-1)	0.12	0.04	2.73	0.0137
	Δln(K)(-2)	0.09	0.04	2.07	0.0534
	Δln(L)	0.07	0.06	1.14	0.2690
	Constant	-0.52	0.09	-6.05	0.0000
	ECT_{t-1}	-0.40	0.06	-6.24	0.0000

The coefficient ECT_{t-1} signifies the error-correction term coefficient of this model. Upon scrutinizing the outcomes of the short term ARDL test, it becomes evident that our error-correction coefficient aligns with the anticipated range, falling between -1 and 0. Furthermore, upon assessing the coefficient alongside its associated probability value, statistical significance is observed. However, caution is warranted when relying solely on the probability value to gauge the significance of the error correction coefficient. Hence, it becomes essential to subject the t-statistic to a bounds test. The bounds test for the t-statistic of the ECT is presented as follows:

Table 7: Error Correction Coefficient t-Bounds Test Results

t-stat	Bounds Test Critical Value	
	***I* [0]**	***I* [1]**
-6.24	-3.43	-4.37
Notes: At the 1% significance level, the critical values corresponding to the t-statistic are noted as 3.43 for the lower boundary and -4.37 for the upper boundary. Consequently, ECT_{t-1} displayed statistical significance at the 1% significance level.		

ECT holds statistical significance and collaborates with the outcome of the bounds test for the error correction coefficient. Hence, this signifies that a short-term deviation is rectified within a span of 2.5 years (1/0.40) and leads the system back to long-term equilibrium.

When opting for the suitable VAR model for the VAR-Granger causality test, an assessment of root stability, stationarity, autocorrelation, and heteroskedasticity tests was executed. To ensure the stationarity of the series, differencing was applied and sustained. In the chosen VAR model, no indications of autocorrelation or heteroskedasticity issues were observed, and the roots remained stable. The findings from the Granger causality test are outlined in the subsequent section.

Table 8: Granger Causality Test Results

Dependent Variables	Independent Variables	Chi-Square (χ²)	Direction of the Relationship
ΔlnGDP	ΔlnEC	10.02*** (0.0067)	EC→ GDP
	ΔlnK	7.21** (0.0272)	K→ GDP
	ΔlnL	2.78 (0.2492)	L ↛ GDP
ΔlnEC	ΔlnGDP	1.13 (0.5694)	GDP ↛ EC
ΔlnK	ΔlnEC	7.50** (0.0235)	EC→ K

Note: The values enclosed in parentheses denote the corresponding probability values, while *, **, and *** indicate the critical values at the 10%, 5%, and 1% significance levels, respectively.

According to the results obtained from the Granger Causality Test, a short-term Granger causality relationship was found from EC to EG, from EG to EC and finally from K to EG at a significance level of 5%. However, no Granger causality relationship was found between the labor variable and growth. When the interaction between EC and EG is evaluated comprehensively, it is seen that the growth hypothesis is valid in the context of the sample analyzed from Türkiye.

5. CONCLUSION

Various economic theories offer distinct perspectives on the concept of energy. In neoclassical theory, energy is recognized as an intermediate good rather than a direct production factor. This stance arises from the belief that economic growth and technological advancements will avert the risk of natural resource depletion. Essentially, proponents contend that human-made capital will perpetually replace natural capital. In the context of endogenous growth theory, energy similarly assumes the role of an intermediate good. However, scholars within this framework assert that the substitutability of energy is constrained. Moreover, technological advancements are deemed essential to mitigate energy costs and enhance its efficiency, given that growth could be restricted without adequate energy, thereby emphasizing the significance of sustainable growth. Conversely, the biophysical theory introduces a distinct perspective, attributing a pivotal role to energy in economic growth. Notably, proponents of this theory emphasize energy's critical contribution to the industrial revolution. According to biophysical economist Roegen, energy stands as a fundamental factor of production. He asserts that growth might decelerate or even halt due to the finite nature of energy resources, unable to regenerate once consumed.

In this study, the relationship between energy consumption and economic growth was investigated by designing a growth model by evaluating the energy factor as an intermediate good using the Cobb Douglas model. Accordingly, the formulated model captures the indirect impact of energy on production through the mediating factors of labor and capital within the productivity equation. In this model, key variables encompass real GDP, L (employment), real K (gross fixed capital investments) and total final ELC (electricity consumption). Given that the variables' unit root results were not I(2), the ARDL bounds test was chosen. The estimated model unveiled a long-term cointegration relationship among the variables at a significant level of 1%. Drawing from the long term ARDL findings, a 1% increase in EC (energy consumption) corresponds to a 0.20% enhancement in EG (real GDP), while a 1% elevation in gross fixed capital investment leads to a 0.34% rise. Additionally, a 1% upsurge in the labor variable is projected to result in a substantial 0.82% boost in real GDP.

The statistically significant error correction coefficient, coupled with the outcome of the boundary test for said coefficient, demonstrates the efficacy of the error correction mechanism. As such, deviations from the equilibrium state are rectified over a period of 2.5 years (1/0.40) and eventually restore the system to long-term stability.

Furthermore, the outcomes of the Granger Causalityof Test display notable findings. Based on the results of the Granger Causality Test, a significant short- term Granger causality was identified at the 5% significance level from EC to EG, from EG to EC, and from K to EG. However, no evidence of Granger causality was found between the labor variable and economic growth. A thorough evaluation of the interaction between EC and EG indicates that the growth hypothesis holds true within the context of the sample analyzed from Türkiye.

The findings in this study are consistent with the findings in the studies conducted by Shahbaz, Khan and Tahir (2013), Shiu and Lam (2004) on the Chinese economy, Gupta and Sahu (2009) on the Indian economy, Bowden and Payne (2009), Stern (1993), Yu and Jin (1992) on the USA economy, Ang (2007) on the French economy, Ho and Siu (2007) on the Hong Kong economy, Jobert and Karanfil (2007), Altınay and Karagol (2005), Soytas and Sarı (2003) on Türkiye. Jobert and Karanfil (2007) examined the period 1960-2003 in the Turkish economy, Altınay and Karagol (2005) on the period 1950-2000, Soytas and Sari (2003) on the period 1950-1992 and found that the growth hypothesis was valid in Türkiye, and reached similar conclusions with this study. However, in another study on the Turkish economy, Altınay and Karagol (2005) concluded that the neutrality hypothesis was valid in the period 1950-2000, Ucak and Usupbeyli (2015) in the period 1971-2013, and Lise and Van Montfort (2007) in the period 1970-2003, and the protection hypothesis was valid.

In light of these findings, it is crucial for policymakers to develop a range of energy-focused strategies to ensure sustainable economic growth in Türkiye. First, investments aimed at enhancing energy efficiency should be encouraged. Given that energy consumption supports economic growth, improving energy usage efficiency will contribute positively to this growth. Promoting energy-saving technologies, particularly in the industrial and service sectors, will not only reduce energy costs but also lessen environmental impacts. Furthermore, investments in renewable energy sources should be increased. Considering the strong relationship between current energy consumption and economic growth, transitioning to renewable energy is strategically important for reducing dependency on limited energy resources. This shift will enhance energy security while paving the way for long-term sustainable growth. Additionally, fostering technological innovations that improve energy efficiency through R&D activities will support growth and reduce energy costs. Strengthening public-private partnerships can further increase investments in innovative energy solutions.

Future research could expand on the relationship between energy consumption and economic growth in several ways. Analyzing the individual impacts of different energy sources (fossil fuels and renewables) can help identify which are more efficient. Moreover, exploring the dynamics of energy consumption and economic growth on a sectoral basis (such as industry, services, and agriculture) would provide deeper insights. Focusing more on the contributions of energy efficiency and technological advancements to growth can assist in formulating more effective policies.

REFERENCES

Alam, M. S. (2006). "Economic Growth With Energy", *Munich Personal RePEc Archive 2006*, Working Paper No: 1260, 1-25.

Alam, I., & Quazi, R. (2003). "Determinants of Capital Flight: An Econometric Case Study of Bangladesh", International *Review of Applied Economics*, 17(1), 85-103.

Altinay, G., & Karagol, E. (2005). "Electricity Consumption and Economic Growth: Evidence from Turkey", *Energy Economics*, 27, 849-856.

Altinay, G., & Karagol, E. (2004). "Structural Break, Unit Root, and The Causality between Energy Consumption and GDP in Turkey", *Energy Economics*, 26(6), 985-994.

Ang, J. B. (2007). "CO2 Emissions, Energy Consumption, and Output in France", *Energy Policy*, 35(10), 4772-4778.

Ayres, R. U., Van den Bergh, J. C., Lindenberger, D., & Warr, B. (2013). "The underestimated contribution of energy to economic growth". *Structural Change and Economic Dynamics*, 27, 79-88.

Bahmani-Oskooee, M. M., & Goswami, G. G. (2003). "A Disaggregated Approach to Test the J-Curve Phenomenon: Japan Versus Her Major Trading Partners", *Journal of Economics and Finance*, 27(1), 102-113.

Banerjee, A., Dolado, J., & Mestre, R. (1998). "Error-correction mechanism tests for cointegration in a single-equation framework". *Journal of time series analysis*, *19*(3), 267-283.

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.

Brown, R. L., Durbin, J., & Evans, J. M. (1975). "Techniques for Testing the Constancy of Regression Relationships Over Time", *Journal of the Royal Statistical Society: Series B (Methodological)*, 37(2), 149-163.

Bulut, Ö. U., Aykırı, M., & Balcı, Ö. (2022). "Elektrik Tüketiminin Ekonomik Büyüme Üzerindeki Asimetrik Etkisi: NARDL ve Toda-Yamamoto Yöntemlerinden Kanıtlar". *Uluslararası Ekonomi ve Yenilik Dergisi*, 8(2), 99-119.

Antunano, A. C., & Alonso, A. Z. (2007). "Electricity consumption and economic growth: Evidence from Spain". *Documentos de Trabajo BILTOKI*, (1), 1.

Cheng, B. S., & Andrews, D. R. (1998). "Energy and economic activity in the United States: Evidence from 1900 to 1945". *Energy sources*, 20(1), 25-33.

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.

Cleveland, G., Schroeder, R. G., & Anderson, J. C. (1989). "A theory of production competence". *Decision sciences*, 20(4), 655-668.

Cottrell, A. (2019). "The cobb-douglas production function". *Economics*, 207, 1-4.

Dickey, D. A., & Fuller, W. A. (1979). "Distribution of the estimators for autoregressive time series with a unit root". *Journal of the American statistical association*, 74 (366a), 427-431.

Douglas, P. H. (1976). "The Cobb-Douglas production function once again: its history, its testing, and some new empirical values". *Journal of political economy*, 84(5), 903-915.

Ekonomou, G., & Halkos, G. (2023). "Exploring the impact of economic growth on the environment: An overview of trends and developments". *Energies*, 16(11), 4497.

Eriçok, R. E. & V. Yılancı (2013). "Education Expenditures and Economic Growth Relationship: Bounds Test Approach", *Journal of Knowlede Economy and Knowledge Management*, 8(1), 87-101.

Gupta, G., & Sahu, N. C. (2009). "Causality between Electricity Consumption & Economic Growth: Empirical Evidence from India". *Munich Personal RePEc Archive*, Paper No. 22942.

Gurgul, H., & Lach, Ł. (2012). "The Electricity Consumption Versus Economic Growth of the Polish Economy", *Energy Economics*, 34(2), 500-510.

Gujarati, D. N. (2004). "Basic Econometrics", *Forth Edition*, 814-818.

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: journal of the Econometric Society*, 424-438.

Granger, C. W. J. & Newbold, P. (1974). "Spurious Regressions in Econometrics", *Journal Of Econometrics*, 2, 111-120.

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.

Houthakker, H. S. (1955). "The Pareto distribution and the Cobb-Douglas production function in activity analysis". *The Review of Economic Studies*, 23(1), 27-31.

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.

Jobert, T., & Karanfil, F. (2007). "Sectoral Energy Consumption by Source and Economic Growth in Turkey", *Energy Policy*, 35(11), 5447-5456.

Johansen, S. & K. Juselius (1990), "Maximum Likelihood Estimation and Inference on Cointegration With Applications to The Demand for Money", *Oxford Bulletin Of Economics and Statistics*, 52, 169-210.

Karaagac, G. E., & Ceylan, R. (2018). "The Analysis of The Relationship Between Energy Consumption and Economic Growth in Selected OECD Countries: Evidences From Cointegration Technique with Structural Break", *Journal of Mehmet Akif Ersoy University Economics and Administrative Sciences Faculty*, 5(2), 204-222.

Kızılkaya, F. (2023). "Türkiye'de Temiz Enerji Tüketiminin Ekonomik Büyüme Üzerindeki Etkileri: Uzun ve Kısa Dönem Analizi". *Uluslararası Akademik Birikim Dergisi*, 6(ÖZEL SAYI).

Kraft, J., & Kraft, A. (1978). "On the relationship between energy and GNP". J*ournal 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 Turkey: Is There A Co-İntegration 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.

Mankiw, N. G., Romer, D., & Weil, D. N. (1992). "A Contribution to the Empirics of Economic Growth", *The Quarterly Journal of Economics*, 107(2), 407-437.

Menegaki, A. N., & Tugcu, C. T. (2016). "The sensitivity of growth, conservation, feedback & neutrality hypotheses to sustainability accounting". *Energy for Sustainable Development*, 34, 77-87.

Narayan, P. K., & Smyth, R. (2005). "Electricity Consumption, Employment and Real Income in Australia Evidence from Multivariate Granger Causality Tests", *Energy Policy*, 33(9), 1109-1116.

Narayan, P. K. & R. Smyth (2005). "Trade Liberalization and Economic Growth in Fiji. An Empirical Assessment Using the ARDL Approach", *Journal of The Asia Pacific Economy*, 10(1), 96-115.

Narayan, P. K. (2005). "The Saving and Investment Nexus for China: Evidence from Cointegration Tests", *Applied Economics*, 37(17), 1979-1990.

Narayan, P. K. & S. Narayan (2005). "Estimating Income and Price Elasticities of Imports For Fiji in a Cointegration Framework", *Economic Modelling*, 22, 423-438.

Narayan, P. K. & R. Smyth (2006). "What Determines Migration Flows from Low-Income to High-Income Countries? An Empirical İnvestigation of Fiji-U.S. Migration 1972-2001", *Contemporary Economic Policy*, 24(2), 332-342.

Özgün, F. (2024). "Türkiye'de Enerji Tüketimi, Yaşam Beklentisi ve Ekonomik Büyüme İlişkisi: ARDL Sınır Testi Yaklaşımı". *Nişantaşı Üniversitesi Sosyal Bilimler Dergisi*, 12(Özel Sayı), 123-143.

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.

Payne, J. E. (2010). "A Survey of The Electricity Consumption-Growth Literature", *Applied Energy*, 87(3), 723-731.

Perron, P. (1989). "The Great Crash, The Oil Price Shock, and The Unit Root Hypothesis", *Econometrica: Journal of the Econometric Society*, 1361-1401.

Pesaran, M. H., Y. Shin & R. J. Smith (2001). "Bounds Testing Approaches to the Analysis of Level Relationships", *Journal of Applied Econometrics*, 16, 289-326.

Phillips, P. C. B. (1988). "Testing for a Unit Root in Time Series Regression", *Biometrika*.

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.

Sefer, U., & Usupbeyli, A. (2015). "The Causality Relationship Between Oil Consumption and Economic Growth in Turkey". *Ankara University SBF Journal*, *70*(3), 769-787.

Soytas, U., & Sari, R. (2003). "Energy Consumption and GDP: Causality Relationship in G-7 Countries and Emerging Markets", *Energy Economics*, 25(1), 33-37.

Shahbaz, M., Khan, S., & Tahir, M. I. (2013). "The Dynamic Links between Energy Consumption, Economic Growth, Financial Development and Trade in China: Fresh Evidence from Multivariate Framework Analysis", *Energy Economics*, 40, 8-21.

Shiu, A., &Lam, P.-L. (2004). "Electricity Consumption and Economic Growth in China", *Energy Policy*, 32, 47-54.

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. (1993). “Energy and Economic Growth in The USA”, *Energy Economics*, 15(2), 137–150.

Stern, D. I. (2011). “The role of energy in economic growth”. *Annals of the New York Academy of Sciences*, 1219(1), 26-51.

Tang, C. F., Shahbaz, M., & Arouri, M. (2013). “Re-Investigating the Electricity Consumption and Economic Growth Nexus in Portugal”, *Energy Policy*, 62, 1515-1524.

Tang, C. F., Tan, B. W., & Ozturk, I. (2016). “Energy Consumption and Economic Growth in Vietnam”, *Renewable and Sustainable Energy Reviews*, 54, 1506-1514.

Tari, R. &D. Ç. Yildirim (2009). “The Effect of Exchange Rate on Export: An Analysis for Turkey”, *Journal of Management and Economics*, 16(2), 95- 105.

Uçak, S., & Usupbeyli, A. (2015). “Türkiye’de petrol tüketimi ve ekonomik büyüme arasındaki nedensellik ilişkisi”. *Ankara Üniversitesi SBF Dergisi*, 70(3), 769-787.

Uslu, H. (2022). “Türkiye’de finansal gelişme ve enerji tüketiminin ekonomik büyüme üzerindeki etkisi: Yapısal kırılmalı bir analiz”. *Manas Sosyal Araştırmalar Dergisi,* 11(1), 188-217.

Van Zon, A., & Yetkiner, I. H. (2003). “An endogenous growth model with embodied energy-saving technical change”. *Resource and energy economics*, 25(1), 81-103.

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.

Yapraklı, S. (2013). “Enerjiye Dayalı Büyüme Türk Sanayi Sektörü Üzerine Uygulamalar”, *İstanbul: BETA Yayıncılık*, 80-91.

Yaprakli, S., & Yurttancikmaz Z. C. (2012). “Causality Between Electricity Consumption and Economic Growth: An Econometric Analysis on Turkey”. *Cumhuriyet University Journal of Economics & Administrative Sciences Journal*, 13(2).

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.

Disclosure Statements (Beyan ve Açıklamalar)

1. The authors of this article confirm that their work complies with the principles of research and publication ethics (Bu çalışmanın yazarları, araştırma ve yayın etiği ilkelerine uyduklarını kabul etmektedirler).

2. No potential conflict of interest was reported by the authors (Yazarlar tarafından herhangi bir çıkar çatışması beyan edilmemiştir).

3. This article was screened for potential plagiarism using a plagiarism screening program (Bu çalışma, intihal tarama programı kullanılarak intihal taramasından geçirilmiştir).