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Enerji Tüketimi, CO2 Emisyonu ve Ekonomik Büyüme İlişkisi: Türkiye için ARDL Analizi

Energy Consumption, CO2 Emissions, and Economic Growth Nexus: ARDL Analysis for Turkiye

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Öz

Türkiye'nin 100. yılını kutladığı bu dönemde, sürdürülebilir ve kapsayıcı ekonomik büyüme Türkiye ekonomisinin geleceği için önemli bir konudur. Bu bağlamda, bu çalışmada 1990-2021 dönemi için, ekonomik büyüme, CO2 emisyonu, enerji tüketimi ve sabit sermaye oluşumu değişkenleri kullanılarak sınır eşbütünleşme yaklaşımı ve Granger nedensellik testi uygulanmıştır. Sonuçlar, ekonomik büyüme ile CO2 arasında uzun vadeli pozitif bir ilişki olduğunu göstermektedir. Ayrıca, sonuçlar tarafsızlık hipotezini desteklemektedir. Çevresel kaygılar dikkate alınarak, politika yapıcılar için, vergi indirimi gibi teşvikler sunarak yenilenebilir enerji tesislerine yatırım yapılması önem arz etmektedir. Eş zamanlı olarak, ekonomik ilerlemenin artan CO2 emisyonu ile olan ilişkisi, daha temiz sanayi süreçleri ve geliştirilmiş enerji verimliliği için çaba sarf etmenin önemini vurgulamaktadır. Ayrıca, birçok çalışmanın çeşitli bulguları göz önüne alındığında, politikaları en güncel ve en doğru verilere dayandırarak araştırmaları sürdürmek gerekmektedir.

Anahtar Kelimeler: Ekonomik büyüme; Enerji tüketimi; Sınır Eşbütünleşme testi; CO2 emisyonları; Türkiye

ABSTRACT

As Turkiye celebrates its 100th year, planning for sustainable and inclusive economic growth for Turkiye's future is crucial. In this context, this paper investigates the association between economic evolution and CO2 releases, energy usage, and gross fixed capital formation; utilizing the Bounds Cointegration test and Granger-causality test during the period spanning from 1990 to 2021. The results validate the long-run relationship between economic evolution and CO2. Moreover, the findings endorse the neutrality hypothesis. For policymakers, it's crucial to champion investments in renewable energy platforms, potentially by offering incentives such as tax breaks. Concurrently, the correlation between economic progress and growing CO2 releases signals the importance of pushing for cleaner industrial processes and enhanced energy efficiency. Moreover, given the varied findings of several studies, it's necessary to perpetuate ongoing research to base policies on the latest and most exact data present.

Keywords: Economic growth; Energy consumption; Bounds Cointegration test, CO2 emissions, Turkiye

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INTRODUCTION:

Economic sustainability and growth are the primary ambition for every country (Zahonogo, 2016). The economic sustainability is influenced by climate change and environmental deterioration (Ozili, 2020). Climate change poses economic challenges that may adversely affect human well-being and livelihoods. To address these threats, society needs to make collective decisions, implement strategic plans, and predict future climatic changes considering greenhouse gas releases and patterns of socio-economic progression. Human-made industrial emissions are a primary cause of climate change, indicating a critical global concern. As levels of carbon dioxide grow yearly, there's a need to reconcile economic growth, driven by energy sources, with environmentally sustainable solutions. Mixed findings have emerged regarding the nexus between environmental harm and economic development. Multiple studies suggest that an uptick in individual income levels might intensify environmental deterioration. Conversely, some studies posit that the capability of a country to tackle climate issues is fortified by its economic expansion, however, some concerns should be considered such as effective institutional structures, the standard of education, and the financial sector. In Turkiye, environmental problems have grown, and although the performed environmental strategies have provided certain advantages, factors like the utilization of natural resources stemming from economic expansion, population growth, industrialization, and accelerated urban growth uninterruptedly imposed on the environment. This matter brings forth new complexities and vulnerabilities in climate change areas.

Through this lens, this research will enhance the prevailing literature by offering a contemporary evaluation of the bond between economic evolution and CO2 releases, which form the majority of greenhouse gas releases. The yearly 0.5% growth in CO2 is due to the increasing CO2 amounts in the atmosphere, which represents approximately 60% of the greenhouse effect induced by human activities. Currently, the yearly emission of CO2 escalated to 2 billion tons throughout the 20th century and to 24 billion tons at the start of the 21st century, reaching 37.1 billion tons in 2018 (Şahinöz, 2021). Assuming this upward pattern persists at this rate, the concentration of CO2 in the atmosphere will inevitably double within 140 years (Huang et al., 2020). If immediate actions aren't adopted globally and anthropogenic greenhouse gas discharges are not decreased, then the aspects of the climate crisis will expand further and bring about severe perils to natural life (Miçooğulları, 2022). Thus, several institutions, agencies, and researchers are increasingly adopting primary green transition tactics to lessen environmental degradation. Within this framework, advanced countries and the international community have commenced significant international initiatives to offset the negative results of greenhouse gas emissions. These initiatives encompass the United Nations Framework Convention on Climate Change (UNFCCC), the Montreal Protocol, the European Union (EU) Green Deal, the Kyoto Protocol, and the Paris Agreement (UNEP, 2016).

Alongside the united endeavors of the global community, researchers emphasize the variables that retain and/or boost economic growth such as gross fixed capital formation and energy usage. Halıcıoglu (2009) underscored that economic evolution and energy usage go hand in hand, and in turn, enhanced energy efficiency necessitates advanced economic stages. Besides, even though pouring resources into infrastructure and industrial sectors commonly amplifies energy consumption, allocating capital to newer, superior efficiency systems and structures can yield enhanced energy conservation in the future. Hence, even if gross fixed capital formation (GFCF) may first prompt an uptick in energy usage, the nature and proficiency of that investment prove consequential in the long-term perspective. Furthermore, while energy ignites economic momentum, which in turn leads to greater CO2 emissions (Ying and Wenbo, 2020), policies, technological innovation, and shifts in energy sources can foster truly sustainable economic endeavors. The primary contributions this paper are outlined below: i) In light of the current global shift towards sustainability, particularly with initiatives like the Green Deal, examining the connection between economic evolution and CO_2 releases, energy usage and gross fixed capital formation is increasingly vital for Turkiye as it aligns its national policies with global environmental goals. ii) investigating the impact of energy usage on economic evolution utilizing electricity consumption from renewables. iii) investigating the impact of CO_2 releases on economic evolution. iv) investigating the gross fixed capital formation on economic evolution. v) This paper utilized the Bounds-Cointegration test and Granger-causality test. This approach comprehensively captures the nuanced nexus between GDP, energy usage, and CO_2 releases throughout both short- and long-run timespans. Furthermore, it is considered the best econometric approach when the variables have a stationary status at I(0) or exhibit integration of order I(1) (Menegaki, 2019). The structure of this research is sequenced thusly: Section 2 highlights the literature overview; Section 3 delves into the data and methodological approach; Section 4 unveils the empirical conclusions, and Section 5 wraps up with concluding remarks and suggested policies.

1. Literature Review:

1.1. Economic growth and CO2 emissions

Over the last two decades, there has been a growing inclination to examine evolution strategies concerning climate change, global warming, and the greenhouse phenomenon. A significant portion of the literature emphasizes the nexus between environmental pollutants and output, predominantly with the goal of confirming the EKC theory, which posits that pollution increases as a nation prospers but begins to decrease when incomes surpass a certain limit (Grossman and Krueger, 1991; Ulucak and Bilgili, 2018 and Ali et al., 2021). Other inquiries probed the nexus between economic evolution and CO_2 releases ruminating other variables. In this study, we delve into investigating the bond between economic evolution and CO_2 releases, considering GDP (the proxy of economic evolution) as the dependent variable. Bilan et al. (2019) affirmed the bond between GDP, renewable energy supplies, and CO_2 releases. Azam et al. (2016) delve into the bond between CO_2 releases per capita and economic evolution in prominent economies like India, China, Japan, and the USA spanning from 1971 to 2013, incorporating variables like energy usage, trade, and human capital. Utilizing the panel (FMOLS) approach, the research deduces that while CO_2 emissions and energy use impede economic ascent as a whole, trade and human capital offer positive boosts. However, in specific nation-based assessments, CO_2 emissions positively correlate with evolution in Japan, China, and the USA but inversely in India. These nuanced outcomes accentuate the need for policies targeting pollution reduction to bolster sustainable progress and societal well-being. Onofrei et al. (2022) investigated the dynamics between economic evolution and CO_2 releases among the 27 EU member countries spanning from 2000 to 2017. Employing a mix of qualitative and quantitative approaches, such as unit root tests, Dynamic Ordinary Least Squares (DOLS), and cointegration techniques, they discerned a consistent correlation between economic evolution and CO_2 releases. The observational findings unveiled that a 1% surge in GDP typically yields a 0.072% increase in CO_2 releases. The study brings to the fore that prosperous economies' inclination for environmental conservation doesn't reduce climate vulnerability. Instead, the nature of growth emerges as instrumental. The study impels EU policymakers to balance economic growth with judicious climate threat response strategies. Similar results had been recorded at the country level, for instance, the studies conducted by Yousefi-Sahzabi et al. (2011), Bouznit and María del (2016), and Lešáková and Ondřej (2018) for Iran, Algeria, and the Czech Republic respectively. Breed et al. (2021) delve into the implications of Europe's fuel economy regulations, pressing truck producers to achieve a 30% plummet in CO_2 emissions by 2030, relative to 2019/2020 levels. Responding to this, manufacturers have voiced their trajectory towards proclaiming the advent of zero-emission vehicles (ZEVs), encompassing options like battery-powered or fuel-cell vehicles. The study pioneers in probing the projected sales proportion of these ZEV trucks that's quintessential for resonating with the set emission paradigms. Data culled indicates that in order to meet the 2030 regulations, 4–22% of new heavy-duty vehicles sold must be emission-free, which would mirror a ZEV ownership fraction of 2–11% across Europe come 2030. An appended advisory of the paper, though, is the potential downside that the high ZEV sales shares and super credits offered by regulations could enable manufacturers to achieve their targets, albeit without materially trimming CO2 emissions in their traditional fleet. Jiang and Guan (2016) meticulously evaluated the surge in global CO2 releases, categorizing them by fossil fuel type, demand, country development status, and industry group. Their inferences pinpoint that during the period spanning 1995–2009, CO2 emissions anchored to coal experienced the most rapid growth in emerging nations, increasing by 3.76 Gt. In contrast, releases from natural gas usage rose the quickest in advanced nations, accounting for an extra 470 Mt. Even with the strides towards energy efficiency, infrastructural augmentations and evolving electricity needs in developing nations, particularly in China, have fanned the flames of CO2 emissions from coal combustion. To narrow down on China, coal-related CO2 emissions increased by 2.79 Gt during the same period. Veering to the developed countries, public and social services consumption and chemical products were the catalysts for the increase in the CO2 emissions from natural gas, with the US contributing up to a 100 Mt increase credited to its natural gas consumption. Dogan and Seker (2016) undertook a detailed examination of the determinants behind CO2 emissions. They highlight that many studies heavily rely on aggregate energy consumption data, neglecting the crucial aspect of weighing cross-sectional dependence in their methodologies. Utilizing the Environmental Kuznets Curve (EKC) framework, their inquiry probed the influence of green and conventional energy, actual income, and trade liberalization on CO2 releases within the European Union from 1980 to 2012. Their techniques catered to cross-sectional dependence. Outcomes indicate that non-renewable energy sources heighten carbon releases, while renewable energy and trade openness decrease them. Moreover, their findings indicated that the EKC hypothesis, which anticipates a U-shaped relation between economic development and environmental deterioration, holds true. Furthermore, their causality analysis unveils a two-way nexus between renewable energy and carbon releases, and a unidirectional causal nexus from actual income to carbon releases, CO2 releases to non-renewable energy, and trade liberalization to CO2 releases.

In the context of Turkiye, Uğur (2022) delves into the impacts of foreign direct investments (FDI), energy usage, and economic progression on CO2 releases in Turkiye during the period spanning 1974-2015; utilizing the (ARDL) model, featuring a structural break, with FMOLS, DOLS, and CCR estimators to assess the accuracy of the analysis. The deduced insights affirm the existence of a persistent nexus between the examined variables. Considerably, FDI correlates positively with CO2 emissions, bolstering the pollution haven hypothesis. Economic growth, proxied by GDP, exacerbates CO2 emissions, albeit the squared GDP exhibits a negative effect, reinforcing the (EKC) hypothesis. Higher energy usage correlates with increased environmental deterioration. Uğur underscores that the increase in carbon emissions stemming from FDI necessitates Turkiye's gravitation to eco-friendly technologies to rein in environmental degradation. Katircioglu and Katircioglu (2018) delved into the repercussions of urbanization on the (EKC) in the context of Turkiye's rapidly urbanizing developing economy. Their insights correlate the surge in carbon dioxide releases with the usage of fuel oil and conventional energy habits arising from urban growth. The results revealed that Turkiye's EKC does not resonate with the conventional inverted U model. Thus, Turkiye needs a transition towards cleaner energy infrastructures. The prevalent literature on the bond between economic evolution and CO2 underscores the need for transitioning to cleaner energy infrastructures and the need for further research to map strategies that ensure both economic growth and environmental sustainability.

1.2. Economic Growth and Energy Consumption

Both neoclassical and endogenous growth theories examine the impact of fundamental production elements, particularly capital and labor, on economic evolution. Those models regularly exclude or, at most, deem the energy and its specific types utilized in the process of production as an intermediate input. Solow considers technological progress as the sole exogenous driver for maintained economic growth, albeit endogenous growth models later incorporated technological progress as a consequence of firm and individual decisions within the growth model itself (Ucan et al., 2014). Stern (1998) underscores that Solow's 1956 neoclassical model does not incorporate resources. Through this perspective, energy can be inferred to be instrumental in the process of economic growth. As economies have transitioned from agriculture-based to industry-based over time, energy's significance in economic growth has become increasingly clear (Ucan et al., 2014). In conjunction with this evolution, environmental challenges such as global warming, pollution, and climate change have arisen, leading to heightened attention on the significance and nature of energy in the growth process by scholars and investigators. Accordingly, an augmented interest in the nexus between energy usage and economic evolution has arisen. Literature has put forth four hypotheses open to verification, regarding the nexus between EG and EC (Ozturk, 2010; Shahbaz et al., 2015).

The Growth Hypothesis posits that EC has a direct impact on EG, even when accounting for the factors of capital and labor. This hypothesis maintains that EC causes EG. This means that if policies are implemented to decrease energy consumption for conservation purposes, it could have a negative impact on EG (Pao and Tsai (2010); Odhiambo (2010); Apergis and Payne (2010a); Menyah and Wolde -Rufael (2010); Al-mulali and Binti Che Sab (2012); Shahbaz et al. (2013); Adegbemi et al., (2013); Apergis and Tang (2013); Aslan et al. (2013); Fang, Y. (2011); Tang et al. (2016); Payne (2011); Inglesi-Lotz (2016)). Inglesi-Lotz (2016) highlights the increasing worldwide significance of renewable energy and explores the less-examined impacts of renewable energy usage on economic well-being, employing panel data methods. The conclusions revealed a positive bond between renewable energy usage and economic evolution, indicating that promoting renewable energy not only responds to environmental issues but also stimulates economic evolution. Utilizing cointegration and Granger causality approaches, Tang et al. (2016) studied the bond between energy usage and economic evolution spanning 1971-2011 in Vietnam. The inferences suggested a positive bond between Vietnam's economic evolution and energy usage, FDI, and capital stock. Furthermore, the conclusions revealed a one-way causality running from energy to economic evolution. These findings emphasize Vietnam's reliance on energy to drive its economic growth. Thus, emphasizing renewable energy plans can ensure an uninterrupted energy supply for sustained economic growth. Investments in R&D can spark advancements in this domain, and public awareness campaigns can bolster these efforts, syncing them with socio-economic growth goals. Apergis and Tang (2013) examined the bond between energy usage and economic evolution across 85 countries. The research revealed that models with three or four variables more efficiently endorse the energy-led growth theory than those with two variables. Moreover, this theory is supported in advanced and developing nations more than in less advanced or low-income countries.

The Conservative Hypothesis suggests that EG is the main driving force behind EC. According to this hypothesis, EG causes EC. This conveys that implementing energy conservation policies to curtail energy usage wouldn't exert an adverse outcome on the economy (Stern and Enflo (2013); Omri and Mabrou (2014); Jacques (2010); Sadorsky (2009) and Ocal and Aslan (2013)). Ocal and Aslan (2013) explored the nexus between renewable energy usage and economic evolution in Turkiye; utilizing the ARDL approach. The results revealed a negative mien of renewable energy usage on economic evolution. Moreover, the conclusions of the Toda–Yamamoto causality tests revealed that economic evolution causes renewable energy usage. In 17 advanced and developing countries, Omri et al. (2015)

explored the causal nexus between two types of energy variables and economic evolution. The consequences indicated that nuclear usage causes economic evolution in Belgium and Spain, but economic evolution causes nuclear consumption in Canada, Bulgaria, the Netherlands, and Sweden. Moreover, in Argentina, growth causes renewable consumption; but renewables cause growth in India. Furthermore, a tow-way nexus was supported in Canada, but no causality in Brazil and Finland.

The Feedback Hypothesis posits that there is a two-way causal nexus between EC and EG, implying that they exert a mutual impact on each other. In this scenario, the adoption of energy conservation policies aimed at curbing EC may have an adverse outcome on EG, and these changes could also have a corresponding impact on energy consumption (Apergis and Payne (2010b); Fuinhas and Marques (2012); Apergis and Payne (2011b); Belke et al. (2011); Solarin and Shahbaz (2013); Tang and Tan (2013); Kyophilavong et al. (2015); Ohler and Fetters (2014); Lin and Moubarak (2014); Medee, Ikue-John, and Amabuike, (2018); Bloch et al., (2015); Apergis and Payne (2012); Shahbaz et al., (2012); Mohammadi and Parvaresh, (2014); Shahbaz et al. (2015); Adams et al., (2016); and Chang et al. (2015)). Kyophilavong et al. (2015) investigated the nexus between trade openness, energy usage, and economic growth in Thailand, utilizing the Bayer and Hanck cointegration method. The conclusions revealed a long-run nexus between the studied variables. Furthermore, the causality results revealed mutual impacts between energy usage and economic evolution, and between trade liberalization and energy usage. The investigation emphasized the necessity for Thailand to formulate cohesive energy and trade strategies to maintain its long-term economic evolution. Medee, Ikue-John, and Amabuike (2018) investigated the causal nexus between economic evolution and energy usage in ten OPEC countries spanning 1970-2014. The results revealed a bidirectional nexus between economic evolution and renewable energy usage. The research suggests implementing strategies that augment energy supply and distribution to boost production and overall economic performance.

The Neutrality Hypothesis claims that EC doesn't influence EG. It suggests that there is no causal nexus between EC and EG. This hypothesis is validated when there's no indication of a causal link between EC and EG; in this situation, the adoption of energy conservation policies targeted at curbing EC would have no impact on EG (Yıldırım et al., (2014); Karanfil and Li (2015); Mesbah (2016) and Menegaki (2011)). Mesbah (2016) delved into Egypt's energy challenges after the 2011 revolution, characterized by frequent power outages and energy shortages. Utilizing a modified Granger causality test with potential structural breaks, and employing a multivariate approach considering capital, labor, and specific energy sources, Mesbah revealed that the neutrality hypothesis holds true during the period from 1980 to 2012. Moreover, evidence supporting the conservation hypothesis was found, suggesting a one-way nexus originating from economic evolution towards electricity and oil usage. Therefore, energy conservation strategies are unlikely to hamper Egypt's future economic aspirations. The literature has produced mixed results due to variations in methods used, timespans studied, and samples analyzed.

In the context of Turkiye, Soytaş and Sari (2003) demonstrated a unidirectional nexus from EC to EG in Turkiye by utilizing co-integration and vector error correction methods for the period (1950-1992). Contrarily, Yalta (2011) found no causality between EC and EG in Turkiye (over both short and long-run), employing the maximum entropy bootstrap method for the period (1950-2006). Moreover, Kaplan et al. (2011) exposed a two-way causative link between EC and Turkish economic evolution in the long run, utilizing the vector error correction model for the period (1971-2006). This result had been supported by Fuinhas and Marques (2012) for the period (1965-2009). Furthermore, Ocal and Aslan (2013) supported the conservation hypothesis in Turkiye; by utilizing the Toda-Yamamoto causality approach for the period 1990-2010. Lise and Van Montfort (2007) delved into the nexus between energy usage and GDP in Turkiye utilizing annual data spanning from 1970 to 2003. The results revealed a one-way causality running from GDP to energy usage, conveying that endeavors to curtail energy usage won't curtail Turkiye's economic growth. Moreover, as the Turkish economy flourishes, so does its energy appetite. Altıntaş (2013) investigated the nexus between carbon dioxide releases, per capita income, energy usage, and investments in Turkiye spanning 1970-2008. The results revealed a co-integrated nexus between these factors and identified a short-term causality running from economic evolution and energy usage to CO2 releases. In the long run, energy usage, economic evolution, and investments markedly steer CO2 emissions. The inferences articulate that as primary contributors to Turkiye's economic evolution, energy usage, and investments also increase pollution, emphasizing the imperative for greener energy alternatives. Çetintaş et al. (2016) delved into the short and long-term impacts of energy usage, economic evolution, and urbanization rate on carbon dioxide emissions in Turkiye spanning 1960-2011. Their inquiry yielded validation for a long-term nexus among these variables. In the long run, energy usage, economic evolution, and urbanization rate bear a positive influence on CO2 releases. However, in the short term, economic evolution and urbanization rates remain inconsequential in influencing CO2 emissions.

The primary additions of this paper to existing literature are diverse. With the global shift towards green practices, particularly with initiatives like the Green Deal, delving into the bond between economic evolution and CO2 releases, energy usage through the lens of electricity consumption from renewables, and gross fixed capital formation has become essential for Turkiye as it strives to harmonize its strategies with worldwide environmental objectives.

2. Data and Methodology:

We put forth appraising the nexus between economic evolution (GDP), electricity usage from renewables (ECR), gross fixed capital formation (GFCF), and CO2 releases (CO2). Within this framework, Equation 1 gauges economic growth in Turkiye considering the previously indicated factors.

$$\mathrm{GDP}_t = \mathrm{f}(\mathrm{ECR}_t, \mathrm{GFCF}_t, \mathrm{CO2}_\mathrm{t}) \quad (1)$$

In their logarithmic forms, we employed these variables since logarithmic forms facilitate direct interpretations of elasticity and often yield more efficient outcomes than just employing the basic linear equation format (Ehrlich, 1996). The empirical model is presented in Equation (2):

$$LGDP_t = \beta 0 + \beta_{ECR} LECR_t + \beta_{GECEL} LGFCF_t + \beta_{CO2} LCO2_t + \mu_t \quad (2)$$

Where GDP indicates GDP in constant 2015 US$, ECR denotes electricity consumption from renewables measured as (TWh), GFCF denotes gross fixed capital formation (constant 2015 US$), CO2 denotes annual Co2 emissions, and the residual, also known as the error term, is represented by µ. CO2 and ECR data were taken from Our World in Data (OWID). Yet, we gathered the GDP and GFCF data across the timeframe of 1990 to 2021, taken from the World Development Indicators. Concerning cointegration analysis, we applied the ARDL approach articulated by Pesaran et al. (2001). Setting it apart from conventional methods, the merits of the ARDL bounds testing method lie in its ability to analyze enduring nexus between variables with different integration levels, its resilience in countering endogeneity and autocorrelation, and its capability to discern the short-term adjustments from long-standing variables' correlations (Pesaran and Shin, 1999). In a two-step process, the ARDL approach functions. In the initial step, the ARDL unrestricted model is appraised, as showcased in the following Equation:

$$\Delta \mathrm{LGDP_t} = \beta 0 + \beta_{\mathrm{ECR}}\mathrm{LECR_{t-1}} + \beta_{\mathrm{GFCF}}\mathrm{LGFCF_{t-1}} + \beta_{\mathrm{CO2}}\mathrm{LCO_{t-1}} + \sum_{i=1}^{p} \beta_{1i}\Delta \mathrm{LGDP_{t-i}} + \sum_{j=0}^{q} \beta_{2j}\Delta \mathrm{LECR_{t-j}} + \sum_{k=0}^{m} \beta_{3k}\Delta \mathrm{LGFCF_{t-k}} + \sum_{r=0}^{\circ} \beta_{5r}\Delta \mathrm{LCO2_{t-r}} + \mu_t \quad (3)$$

Below are the stated null and alternative hypotheses delineated.

$\boldsymbol{H_0}$: Cointegration does not observed if $\beta_{GDP} = \beta_{ECR} = \beta_{GFCF} = \beta_{CO2} = 0$.

$\boldsymbol{H_1}$: Should there be one or more βk that isn't zero ($\beta_k \neq 0$), then cointegration is evident.

Comparing the F-statistic to both the upper and lower critical limits, if the derived F-statistic exceeds the critical limit, then a cointegrating nexus among the variables is statistically affirmed. In instances where the deduced F-statistic remains below the critical limit, the notion of the null hypothesis, which indicates the non-existence of cointegration, remains intact. The optimal lag was chosen to deal with the impact reaction stemming from the lag sequence. In the event the null hypothesis was negated, the connection in both short and long term would be delineated. As depicted in equation (4), the ARDL model integrates the error correction term (ECT_{t-1}) for short-term dynamics.

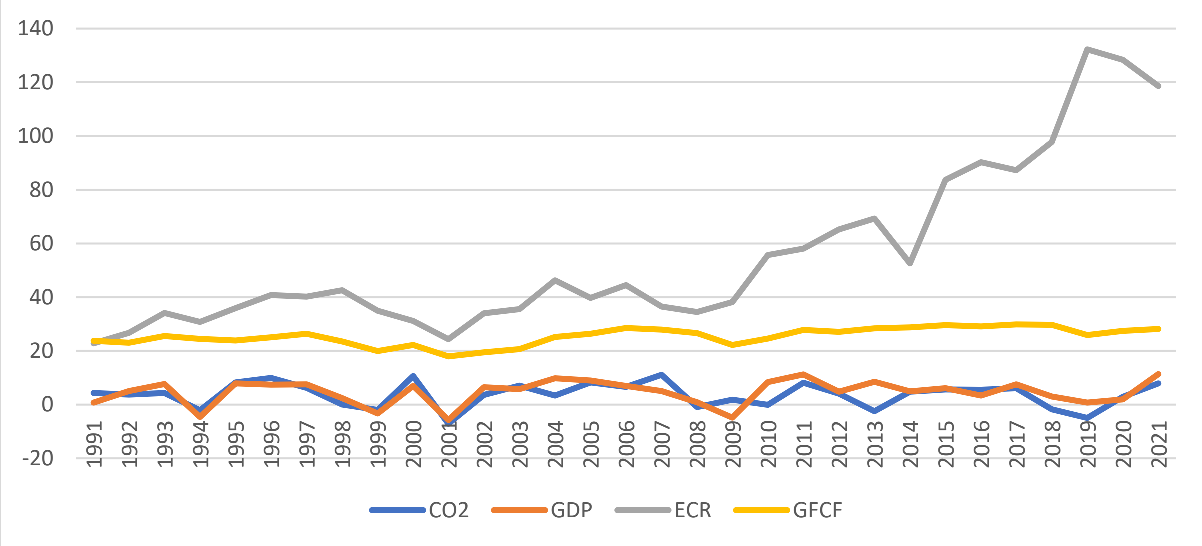
$$\Delta LGDP_t = a0 + \sum_{i=1}^{p} \mathrm{a_{1i}}\Delta \mathrm{LGDP_{t-i}} + \sum_{j=0}^{q} \mathrm{a_{2j}}\Delta \mathrm{LECR_{t-j}} + \sum_{k=0}^{m} \mathrm{a_{3k}}\Delta \mathrm{LGFCF_{t-k}} + \sum_{r=0}^{o} \mathrm{a_{5r}}\Delta \mathrm{LCO2_{t-r}} + \lambda \mathrm{ECT_{t-1}} + \epsilon_t \quad (4)$$

As presented in Equation 4, The λ coefficient symbolizes the error correction coefficient, showcasing the rapidity whereby the model attains long-term equilibrium. It's expected to bear a negative value and to portray statistical noteworthiness. Ultimately, to verify the model's precise specification, it's essential to utilize further diagnostic assessments.

3. Empirical Application:

Figure (1) depicts the macro variables considered for the investigation. The CO2 growth rates data shows an increase of 6.15% and 7.93% in 2017 and 2021 respectively, while 2019 witnessed a decrease of -4.93%. GDP growth rates show significant peaks in 2011 (11.20%) and 2021 (11.35%), but a notable dip in 2009 (-4.82%), suggesting economic fluctuations. ECR increases from 22.8 (TWh) in 1991 to 132.26 (TWh) in 2019. Meanwhile, GFCF (% of GDP) portrays a general upward trajectory, beginning at 23.69 in 1991, reaching a low in 2001 at 17.95, and peaking at 29.86 in 2017.

Figure (1): Variables



For the econometric examination, the initial phase involves effectuating the stationary test. An inherent requirement of the ARDL method is the stipulation that every variable integrate to the highest order of I(1). Therefore, it is imperative to affirm that each variable aligns with the I(0) or I(1) order. To ascertain this, the Dickey-Fuller and Phillips-Perron tests are utilized to ensure that the variables achieve the utmost I(1) integration. Deductions made from Table (1) indicate that, while all other variables display unit roots at their level, they become stationary at the first level. Only results concerning with constant are displayed in table (1).

Table (1): Unit root tests' results

Variables	ADF		PP	
	At level	First Difference	At level	First Difference
GDP	0.5102	-5.5078***	1.7039	-6.3476***
	0.9844	0.0001	0.9994	0.0000
ECR	-0.6941	-6.4049***	-0.3504	-7.0038***
	0.8338	0.0000	0.9058	0.0000
GFCF	-0.7021	-5.9516***	-0.6412	-6.0588***
	0.8318	0.0000	0.8470	0.0000
CO2	-0.8222	-5.6650***	-1.3204	-6.7791***
	0.7987	0.0001	0.6074	0.0000

Notes: (*) marked significance at the 10%; (**) marked significance at the 5%; (***) marked 1% significance. and (no) indicated Not Significant

Then, to explore the potential long-run nexus among the variables, we applied a bound test for ARDL model. The bounds testing approach can be utilized when dealing with variables integrated at either I(0) or I(1) order (Peasaran et al., 2001). Grounded on Akaike information criteria, the optimal lag length is 4 (AIC: -10.53926) and the model's optimal lag selection is (2,2,3,2). The bound test's results are presented in table (2). It indicates that the value of F-stat surpasses in all levels, implying a long-term co-integration of the variables.

Table (2): Outcomes from the Bounds Analysis of the Chosen ARDL (2,2,3,2) Model

F-stat	10%level	5%level	1%level
8.172046	2.676- 3.586	3.272-4.306	4.614- 5.966

* I(0) signifies stationary bounds, whereas I(1) indicates non-stationary bounds.

Moreover, to verify the model's precision we conducted diagnostic assessments. As an initial step, the Breusch-Godfrey serial correlation LM assessment is conducted and table (3) displays that the prob. of the F-statistics exceeds 0.01, suggesting that the model is free from autocorrelation concerns. Subsequently, we utilize the (ARCH) test, observing that the p-value surpasses 0.01, which confirms that the structured model is devoid of heteroscedasticity concerns. Next, we engaged in the Ramsey RESET evaluation, and as shown in table (3), the prob-value associated with the F-statistic is above 0.01, signifying the right selection of the functional form. Subsequently, the Jarque-Bera normality evaluation was executed. With the probability exceeding 0.01, it's evident that the error terms adhere to a Gaussian pattern, indicating the model's alignment with the normality criterion. Next, we performed the stability assessments using both CUSUM of squares and CUSUM. The results showcased the steadiness of the data.

Table (3): ARDL (2,3,2,2) Model Estimation Results and Error Correction Form

Dependent Variable: GDP Model: ARDL (2,3,2,2)			
Long Run			
Variable	Coefficient	t-statistics	Prop.
ECR	0.112	3.784	0.002
GFCF	0.067	1.644	0.120
CO2	0.233	2.468	0.025
Short Run			
ΔGDP(-1)	-0.500	-2.980	0.007
ΔECR	0.039	2.576	0.018
ΔGFCF	0.294	10.730	0.000
ΔCO2	0.100	1.454	0.162
ECM(-1)	-0.365	-7.147	0.000
Diagnostic Tests			
	F-Statistics	Prop.	
χ^2_{NORMAL}	1.222	0.543	
χ^2_{SERIAL}	1.350	0.263	
χ^2_{ARCH}	0.025	0.874	
χ^2_{RESET}	4.466	0.052	
CUSUM	Stable		
CUSUMsq	Stable		

Table (3) displays the long and short terms' estimates. The results revealed that, in the long run, a unit surge in CO2 results in an increase of the dependent variable by 0.23 units ($p<0.05$). Moreover, a unit increase of ECR increases the dependent variable by 0.11 units for every unit increase ($p<0.01$). GFCF's impact on the dependent variable is an increase of 0.07 units for every unit increase, but this result isn't statistically significant at the conventional levels ($p>0.1$). The short run conclusions revealed that changes in CO2 increase GDP by 0.10 units. However, this isn't statistically significant ($p>0.1$). Moreover, changes in ECR positively impact GDP by 0.04 units, and this mien is significant at the 5% level. Furthermore, changes in GFCF result in a substantial positive impact on GDP by 0.29 units, which is highly significant. The COINTEQ term holds a meaningful negative impact at 1%, validating the occurrence of a cointegration equation; this means that deviations from equilibrium are corrected by 37 % within one year. The Granger Causality's results had been reported in table (8).

Table (8): Granger Causality Tests

Null Hypothesis:	F-Statistic	Prob.
ECR does not Granger Cause GDP	0.331	0.721
GDP does not Granger Cause ECR	2.892	0.074

The results revealed that since that Prob. superior to 0.05. Therefore, we can't reject the null hypothesis demonstrate that ECR does not Granger cause GDP. Similarly, we can't reject the null hypothesis demonstrate that GDP does not Granger cause ECR. These results support the neutrality hypothesis.

Conclusion:

We attempted to scrutinize the nexus between economic evolution, energy usage from renewables, gross fixed capital formation, and CO2 releases across the span of 1990 to 2021 in Turkiye, making use of the Bounds cointegration test and Granger causality test. In light of the current global shift towards sustainability, particularly with initiatives like the Green Deal, grasping this connection is increasingly vital for Turkiye as it aligns its national policies with global environmental goals. In the long run, CO2 and ECR positively impact GDP, while GFCF's impact isn't significant. No statistically significant mien of CO2 on GDP was recorded in the short run. However, ECR exerts a notable positive influence on GDP, and GFCF's impact is notably strong. The COINTEQ term implies that deviations are corrected by 37 % within one year. The consequences of causality test support the neutrality hypothesis. Our results align with Bilan et al. (2019), Aslan et al. (2013), Karagöl et al. (2007), Yalta (2011), but didn't satisfy Soytaş and Sari (2003), Kaplan et al. (2011), Fuinhas and Marques (2012), and Ocal and Aslan (2013). For policymakers, considering the positive long-term nexus between ECR and GDP, it's imperative to advocate for investments in green energy sources. This aim can be furthered by granting perks such as tax concessions or financial incentives to producers in the renewable energy field (Bilan et al., 2019). The long-run prolonged nexus between CO2 releases and GDP, indicates that economic gains correspond with rising emissions. Hence, it might be crucial to look at international best practices and consider strategies promoting greener industrial methods and heightening energy efficiency. The significant short-run impact of ECR on GDP indicates that policymakers should expedite the evolution and distribution of sustainable energy technologies, considering their direct implications on economic vigor. An evident that variations from the enduring correlation adjust at a brisk pace, nearing 37% annually. The causality analysis affirms the neutrality stance. As such, it's vital for policymakers to tread carefully regarding while formulating strategies. This paper didn't incorporate all variables that impact the relationship between economic evolution, energy usage, and CO2 releases, for example, factors concerned with alternative energy policies, international trade, and developments in renewable energy technology. In addition, the factors that indirectly affect the mentioned nexus didn't be considered such as economic downturns, shifts in global policy, or major technological innovations. These factors besides the mixed results in the literature highlight the necessity for ongoing research. Continuous updates and improvements in methodology can confirm that policy formulations are anchored in the most and latest precise information accessible.

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GENİŞLETİLMİŞ ÖZET

Çalışmanın Amacı:

Bu makalenin ana amacı, bağımlı bir değişken olarak ekonomik büyüme ile enerji tüketimi, brüt sabit sermaye oluşumu ve CO2 emisyonları arasındaki ilişkiyi araştırmaktır.

Araştırma Soruları:

1990-2021 yılları arasında ekonomik büyüme, enerji tüketimi, sabit sermaye oluşumu ve CO2 emisyonları arasında nasıl bir ilişki bulunmaktadır? Eş bütünleşme testi, bu değişkenler arasındaki eşbütünleşme ilişkisini nasıl belirlemektedir? Granger nedensellik testi, bu faktörler arasında nedensellik ilişkisini nasıl belirlemektedir?

Literatür Araştırması:

İklim değişikliği, küresel ısınma ve sera etkisiyle bağlantılı büyüme stratejilerini inceleme eğilimi son yirmi yılda artmıştır. Literatürün önemli bir kısmı, çevresel kirleticiler ile üretim arasındaki ilişkiyi vurgulamaktadır, özellikle Çevresel Kuznets Eğrisi (EKC) hipotezini doğrulamayı amaçlamakta ve bir ülkenin büyümesiyle kirliliğin arttığını, ancak gelirlerin belirli bir eşiği aştığında azalmaya başladığını savunmaktadır (Grossman ve Krueger, 1991; Ulucak ve Bilgili, 2018 ve Ali vd., 2021). Diğer çalışmalar, ekonomik büyüme ve CO2 arasındaki ilişkiyi, diğer değişkenleri de dikkate alarak incelemiştir. Türkiye bağlamında Uğur (2022), 1974-2015 döneminde Türkiye'de CO2 emisyonlarına yabancı doğrudan yatırımların (FDI), enerji tüketiminin ve ekonomik büyümenin etkilerini incelemekte; yapısal bir kırılma içeren Dağıtılmış Gecikmeli Otoregresif modelini kullanarak FMOLS, DOLS ve CCR tahmincileri ile analizin doğruluğunu değerlendirmektedir. Çıkarılan sonuçlar, incelenen değişkenler arasında sürekli bir ilişkinin varlığını doğrulamaktadır. Özellikle FDI, CO2 emisyonlarıyla olumlu bir şekilde ilişkilidir, kirlilik sığınağı hipotezini desteklemektedir. GSYİH ile temsil edilen ekonomik büyüme, CO2 emisyonlarını artırırken, karesel GSYİH olumsuz bir etki göstermekte ve Çevresel Kuznets Eğrisi (EKC) hipotezini güçlendirmektedir. Daha yüksek enerji tüketimi, artan çevresel bozulma ile ilişkilidir. Uğur, FDI'dan kaynaklanan karbon emisyonlarındaki artışın, çevresel bozulmayı sınırlamak için Türkiye'nin çevre dostu teknolojilere yönelmesi gerektiğini vurgulamaktadır. Katircioğlu ve Katircioğlu (2018), Türkiye'nin hızla kentleşen gelişmekte olan ekonomisi bağlamında kentleşmenin Çevresel Kuznets Eğrisi (EKC) üzerindeki etkilerini incelemiştir. Bulguları, karbon dioksit emisyonlarındaki artışı, kentsel gelişmeden kaynaklanan fuel oil ve geleneksel enerji tüketim modelleri ile ilişkilendirmektedir. Sonuçlar, Türkiye'nin EKC'sinin geleneksel ters U modeli ile örtüşmediğini ortaya koymuştur. Bu nedenle, Türkiye'nin daha temiz enerji altyapılarına geçişi gerekmektedir.

Literatür, EG ve EC arasındaki ilişki hakkında Büyüme Hipotezi, Koruyucu Hipotez, Geri Bildirim Hipotezi ve Tarafsızlık Hipotezlerini test etmektedir. Büyüme Hipotezi, EC'nin, sermaye ve işgücü faktörleri dikkate alındığında bile EG üzerinde doğrudan bir etkisi olduğunu ileri sürmektedir. Bu hipotez, EC'nin EG'ye neden olduğunu savunmaktadır. Bu, enerji tasarrufu amacıyla enerji tüketimini azaltmak için politikaların uygulanması durumunda, EG üzerinde olumsuz bir etkisi olabileceği anlamına gelir (Pao ve Tsai (2010); Odhiambo (2010); Apergis ve Payne (2010a); Menyah ve Wolde -Rufael (2010); Al-mulali ve Binti Che Sab (2012); Shahbaz vd. (2013); Adegbemi vd., (2013); Apergis ve Tang (2013); Aslan vd. (2013); Fang, Y. (2011); Tang vd. (2016); Payne (2011); Inglesi-Lotz (2016)). Koruyucu Hipotez, EG'nin EC'nin arkasındaki ana itici güç olduğunu öne sürmektedir. Bu hipoteze göre, EG, EC'ye neden olmaktadır. Bu, enerji tüketimini kısıtlamak için enerji tasarrufu politikalarının uygulanmasının ekonomi üzerinde olumsuz bir etkisi olmadığı anlamına gelir (Stern ve Enflo (2013); Omri ve Mabrou (2014); Jacques (2010); Sadorsky (2009) ve Ocal ve Aslan (2013)). Geri Bildirim Hipotezi, EC ve EG arasında iki yönlü nedensel bir ilişki olduğunu ileri sürmektedir, bu da iki değişkenin birbirleri üzerinde karşılıklı etkileri olduğu anlamına gelir (Apergis ve Payne (2010b); Fuinhas ve Marques (2012); Apergis ve Payne (2011b);

Belke vd. (2011); Solarin ve Shahbaz (2013); Tang ve Tan (2013); Kyophilavong vd. (2015); Ohler ve Fetters (2014); Lin ve Moubarak (2014); Medee, Ikue-John, ve Amabuike, (2018); Bloch vd., (2015); Apergis ve Payne (2012); Shahbaz vd., (2012); Mohammadi ve Parvaresh, (2014); Shahbaz vd. (2015); Adams vd., (2016); ve Chang vd. (2015)). Tarafsızlık Hipotezi, EC'nin EG üzerinde bir etkisinin olmadığını iddia etmektedir. EC ve EG arasında nedensel bir ilişki olmadığını öne sürmektedir (Yıldırım vd., (2014); Karanfil ve Li (2015); Mesbah (2016) ve Menegaki (2011)).

Yöntem:

Bu çalışma, Türkiye'de ekonomik büyüme, yenilenebilir enerji tüketimi, brüt sabit sermaye oluşumu ve CO2 emisyonu arasındaki ilişkiyi değerlendirmeyi amaçlamaktadır. Değişkenler, elastikiyet yorumlarına olanak tanımak için logaritmik forma dönüştürülmüştür. CO2 ve yenilenebilir enerji tüketimi verileri Our World in Data'dan alınmıştır, GSYİH ve brüt sabit sermaye oluşumu verileri 1990-2021 yılları için Dünya Bankası'ndan elde edilmiştir. Çalışmada Eşbütünleşmeyi değerlendirmek için Pesaran ve diğerleri (2001) tarafından geliştirilen ARDL sınır testi yöntemi kullanılmıştır. Bu yöntem, seriler arasındaki uzun vadeli ilişkileri incelemede, otokorelasyon ve endojenlik sorunlarına çözüm getirmede ve kısa vadeli ayarlamaları uzun vadeli ilişkilerden ayırmada öne çıkmaktadır. Eğer eşbütünleşme tespit edilirse, kısa ve uzun vadeli ilişkiler belirlenir. Kısa dönem senaryosu için hata düzeltme terimi eklenir. Son olarak, seri korelasyon, heteroskedastisite, normalite ve model istikrarı için bir dizi tanı testi yürütülmüştür.

Sonuç ve Değerlendirme:

Bu çalışmada Sınır eşbütünleşme testi ve Granger nedensellik testi kullanılarak, Türkiye'de ekonomik büyüme, yenilenebilir enerji tüketimi, brüt sabit sermaye oluşumu ve CO2 emisyonu arasındaki ilişki incelenmiştir. Uzun vadede CO2 ve ECR, GSYİH'ye olumlu etki ederken, GFCF'in etkisi anlamlı çıkmamıştır. Kısa vadede CO2'nin GSYİH üzerinde istatistiksel olarak anlamlı bir etkisi kaydedilmemiştir. Ancak, ECR'nin GSYİH üzerinde anlamlı olumlu bir etkisi vardır ve GFCF'nin etkisi dikkate değerdir. COINTEQ terimi, sapmaların %37'sinin bir yıl içinde düzeltildiğini göstermektedir. Nedensellik testinin sonuçları tarafsızlık hipotezini desteklemektedir. ECR ve GSYİH arasındaki olumlu ilişkinin sonucu, Aslan ve diğerleri (2013) ve Karagöl ve diğerleri (2007) tarafından desteklenmektedir. Ters nedensizlik sonuçları, GSYİH'dan ECR'ye bir nedensellik olmadığını ortaya koymaktadır ve bu sonuç Kaplan ve diğerleri (2011), Fuinhas ve Marques (2012) ve Ocal ve Aslan (2013) tarafından desteklenmemiştir. Politika yapıcılar için, ECR ve GSYİH arasındaki olumlu uzun vadeli ilişkiyi göz önünde bulundurarak, yeşil enerji kaynaklarına teşvik etmek ekonomi için olduğu kadar çevre için de önem arz etmektedir. Bu amaçla, yenilenebilir enerji alanındaki üreticilere vergi muafiyeti veya mali teşvikler gibi avantajlar sağlanabilir. CO2 emisyonları ile GSYİH arasındaki uzun vadeli ilişki, ekonomik kazançların artan emisyonlarla eşleştiğini göstermektedir. Bu nedenle, daha yeşil endüstriyel yöntemleri teşvik eden stratejileri uygulamak ve enerji verimliliğini artırmak önemli olabilir. ECR'nin kısa vadeli GSYİH üzerindeki önemli etkisi, ekonomik canlılık üzerindeki doğrudan etkilerini göz önünde bulundurarak, sürdürülebilir enerji teknolojilerinin evrimini ve dağıtımını hızlandırmanın politika yapıcılar için önemli olduğunu göstermektedir. Dayanıklı ilişkiden kaynaklanan varyasyonların hızla, yılda yaklaşık %37 oranında ayarlandığına dair bir delil bulunmaktadır. Nedensellik analizi tarafsızlık hipotezini onaylar ve GSYİH ve ECR değişikliklerinin karşılıklı olarak etkili olmadığını gösterir. Bu nedenle, stratejileri formüle ederken politika yapıcıların dikkatlice hareket etmesi kritik öneme sahiptir. Sonuçta hem çevresel veriler hem de teorik ve ampirik çalışmalar kapsamında ekonomik çıkarları ve çevresel etkileri gözeten politikaların dikkatlice seçilmesi önem arz etmektedir