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Exploring The Relationship between Energy Sources, CO_2 Emissions and Sustainable Development in Türkiye

Türkiye'de Enerji Kaynakları, CO_2 Emisyonları ve Sürdürülebilir Kalkınma Arasındaki İlişki

Abstract

Sustainable development has become a major focus of attention worldwide, with numerous initiatives aimed at improving economic development, social equality, natural resources consumption, and social and healthy living while preserving the quality of life. Energy consumption is a crucial input to economic activities, but its impact on sustainable development can be both positive and negative. In this study, the impact of renewable and non-renewable energy sources and CO_2 emissions on sustainable development in Turkiye was investigated using time series analysis for the years between 1972 and 2015. The results suggest that increasing the use of renewable energy sources has a positive effect on sustainable development, whereas fossil fuel energy consumption and CO_2 emissions have a negative impact. The findings of this research have important implications for Turkiye's energy policy and its efforts to achieve sustainable development goals.

Özet

Sürdürülebilir kalkınma, küresel düzeyde büyük bir ilgi odağı haline gelmiştir. Bu alanda, ekonomik kalkınmayı artırmayı, sosyal eşitliği sağlamayı, doğal kaynakların tüketimini ve sağlıklı yaşamı geliştirmeyi hedefleyen birçok girişim bulunmaktadır. Ayrıca, yaşam kalitesini korurken sürdürülebilirliği sağlama amacı taşınan bu çabalar, geniş çapta ilgi ve desteği çekmektedir. Enerji tüketimi, ekonomik faaliyetler için önemli bir girdi olmakla birlikte, sürdürülebilir kalkınma üzerindeki etkisi hem olumlu hem de olumsuz olabilmektedir. Bu çalışmada, Türkiye'de yenilenebilir ve yenilenemez enerji kaynaklarının ve CO_2 emisyonlarının 1972 ile 2015 yılları arasında zaman serisi analizi kullanılarak sürdürülebilir kalkınma üzerindeki etkisi araştırılmaktadır. Elde edien sonuçlar, yenilenebilir enerji kaynaklarının kullanımının sürdürülebilir kalkınma üzerinde olumlu bir etkiye sahip olduğunu, fosil yakıt enerjisi tüketimi ve CO_2 emisyonlarının ise olumsuz bir etkisi olduğunu göstermektedir. Söz konusu araştırmanın bulguları, Türkiye'nin enerji politikası ve sürdürülebilir kalkınma hedeflerine ulaşma çabaları için önemli sonuçlar ortaya koymaktadır.

Hale Kırer Silva Lecuna
Assoc. Prof. Dr., Bandırma Onyedi Eylül University, Balıkesir, Turkiye
hkirer@bandirma.edu.tri,
Orcid No: https://orcid.org/0000-0002-1879-3315

Melike Nur Ertekin
MSc., Yapı Kredi Bank, İzmir, Türkiye
melikenurhelvaci@gmail.com,
Orcid No: https://orcid.org/0009-0007-3873-4973

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Information / Bilgilendirme
The master's thesis entitled "Yenilenebilir ve Yenilenemeyen Enerji Tüketimi, CO_2 Salımı ve Sürdürülebilir Kalkınma İlişkisi: Türkiye Örneği (The Relationship Between Renewable and Non-Renewable Energy Consumption, CO_2 Emission And Sustainable Development: The Case of Turkey)" prepared by Melike Nur Ertekin under the supervision of Assoc. Prof. Dr. Hale Kirer Silva Lecuna, has been extensively utilized in this study.

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Introduction

Although sustainability is a concept that has been commonly studied, its history traces back to ancient times. Its origin comes from the Latin word "sustinere". The concept of sustainability is perceived as a framework for contemplating the future, wherein the pursuit of a better quality of life involves striking a balance between environmental, social, and economic factors. The first official definition of sustainable development was made in the Brundtland Report prepared by the World Commission on Environment and Development in 1987. According to this report, sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Report of the World Commission on Environment and Development : Note, 1987). This concept,

which has a long history and is used in all areas of today's world, has an international dimension. With the Industrial Revolution that began in the 18th century, energy became one of the most fundamental factors for the sustainable socio-economic development of nations and the increase in individual welfare (Ünüvar & Keskinkılıç, 2020). Factors such as population growth and technological developments increased energy demand. The issue of energy security has been caused by the belief that fossil fuel supplies will run out in the future and the high reliance on foreign energy sources in the face of rising demand. Furthermore, factors such as climate change, which has global negative consequences, have increased the value of energy (Öymen & Ömeroğlu, 2020). It will be possible to guard these negative effects and have a stable economy if fossil resources are replaced by renewable ones (Hacıimamoğlu & Sandalcılar, 2021).

Sustainable development is explained by its economic, environmental, and social dimensions. To achieve sustainable development, it is important to establish a balanced relationship between these dimensions and show a holistic approach. Energy is considered as an important element of sustainable development and there are two types of energy sources, which are renewable and non-renewable energies. Countries must prioritize diversifying their energy sources and ensuring energy security in order to meet the sustainability requirements outlined by the World Energy Council. Furthermore, it is essential to minimize the environmental consequences of energy consumption, adopt cutting-edge technologies, and educate the public, all of which hold significant importance.

The objective of this research is to investigate the influence of renewable and non-renewable energy sources as well as CO_2 emissions on Turkiye's economic growth, thereby impacting sustainable development. The study aims to establish whether a noteworthy correlation exists among these variables. Analyzing annual data from 1972 to 2015, the subsequent sections encompass a literature review, an explanation of the dataset and the implementation of the analysis. The paper concludes with a discussion and a final summary.

1. Literature Review

The literature is replete with studies that examine the connection between energy use, CO2 emissions, and economic expansion. Kraft & Kraft (1978) are among the pioneering studies that examine the relationship between energy consumption and economic growth. According to the findings obtained in the study, there is a unidirectional causality from gross domestic product (GDP) to gross energy input. At this point, one of the most important turning points in the literature is the Environmental Kuznets Curve (EKC) Hypothesis. The EKC is based on Kuznets' (1955) theory of an inverted U-shaped relationship between income inequality and growth. Grossman & Krueger (1995) proposed a similar inverted U-shaped relationship between income growth and environmental pollution. According to this theory, in the early years of developing countries, as economic growth takes priority, environmental pollution increases. However, as development is achieved, environmental pollution decreases. Perman & Stern (1999), Moomaw & Unruh (1997), Grossman & Krueger (1995, 1996), Stern et al. (1994), Selden & Song (1994); Shafik & Bandyopadhyay (1992) were particularly engaged in exploring the EKC in the 1990s.

One of the factors that amplifies environmental pollution is CO_2 emissions. Their impact on economic expansion and connection to both renewable and non-renewable energy sources are hotly debated issues. In this regard, the number of studies in this area has increased especially in recent years. Some of the research consists of panel data analysis including certain country groups (Acaravcı & Erdoğan, 2018; Ali et al., 2023; Altinoz et al., 2020; Aye & Edoja, 2017; Chen & Huang, 2013; Coondoo & Dinda, 2002; Dimitriadis et al., 2021; Fernández-Amador et al., 2017; Hdom, 2019; Ito, 2016; Koengkan et al., 2020; Lee & Brahmasrene, 2014; Lu, 2017; Magazzino, 2014, 2017; Mahmoodi, 2017; Maku & Ikpuri, 2020; Muhammad, 2019; Radmehr et al., 2021; Rasoulinezhad & Saboori, 2018; Saidi & Hammami, 2015; Wang et al., 2011) whereas others are time-series analysis studies that examine countries individually (Ahmad et al., 2016; Çetin & Sezen, 2018; Dertli & Yinaç, 2018; Durğun & Durğun, 2018; Emir & Bekun, 2019; Karagöl et al., 2007; Khoshnevis Yazdi & Shakouri, 2018; Li et al., 2017; Li-wei, 2012; Long et al., 2015; Özbay & Pehlivan, 2021; Salari et al.,

2021; Shahbaz & LeitÃ£o, 2013; Terzi & Pata, 2016; Turan & Aksoy, 2021; Uyğun & Günay, 2018; Uysal & Yapraklı, 2016; Xiongling, 2016).

The findings about developing country groups differ in different studies since the data set and the methods vary. Magazzino (2017) obtained no causal relationship between GDP and energy use for APEC (Asia-Pacific Economic Cooperation) countries whereas in his study conducted in 2014 for ASEAN (Association of Southeast Asian Nations) countries his analysis results illustrated positive response of economic growth to energy use. Coondoo & Dinda (2002), Mahmoodi (2017) and Koengkan et al. (2020) pointed out that there was a bi-directional relationship between GDP and CO_2 emissions for selected developing countries. Lee & Brahmasrene (2014) found the existence of a long-term equilibrium relationship among these variables for the Association of Southeast Asian Nations. The region displayed an inverse bidirectional relationship between economic growth and CO_2 emissions. In contrast to Coondoo & Dinda (2002), who found a unidirectional relationship from emissions to income, Radmehr et al. (2021) found a bidirectional relationship between economic growth and CO_2 emissions and renewable energy in developed regions.

In the analyses conducted for China, a unidirectional causality from GDP to emissions was found by Li et al. (2017) and Xiongling (2016). The different studies implemented for USA (Salari et al., 2021), India (Ahmad et al., 2016) and Turkiye (Albayrak & Gökçe, 2015; İzgi, 2020) validated the environmental Kuznets hypothesis whereas Khoshnevis Yazdi & Shakouri (2018)'s analysis did not support it. The majority of the researches made for Turkiye indicate the cointegration between the variables of emissions, renewable and nonrenewable energy sources and economic growth (Çetin & Sezen, 2018; Dertli & Yinaç, 2018; Durğun & Durğun, 2018; Özbay & Pehlivan, 2021).

Overall, the extensive body of research in this field highlights the intricate relationships between energy use, CO2 emissions, and economic expansion. These findings contribute to our understanding of the environmental challenges and opportunities associated with economic growth, providing valuable insights for policymakers, researchers, and stakeholders in developing sustainable strategies for a greener future.

2. Analysis

The examination of energy sources and their impact on sustainable development is a critical area of research, particularly in the context of transitioning towards a greener future. This study focuses on analyzing the relationship between renewable and non-renewable energy sources, carbon dioxide (CO_2) emissions, and sustainable development in Turkiye by employing the time series techniques.

Within this framework fossil fuel energy consumption (FOSIL), Gross Domestic Product (GDP), Carbon Dioxide (CO_2) and alternative and nuclear energy (YBILIR) are employed as the proxies of non-renewable energy sources, sustainable development, CO_2 emissions and renewable energy sources, respectively to examine the impact of renewable and non-renewable energy sources and CO_2 emissions on sustainable development in Turkiye. As per the World Bank's definition, alternative and nuclear energy are considered as clean energy that "does not produce carbon dioxide or carbohydrates". Consequently, it serves as a substitute for renewable energy sources, which share the characteristics of being clean and environmentally sustainable. The data set used in the study was obtained from the World Bank. Since the year 2015 is the last available year, analyzed annual data covers the period from 1972 to 2015.

In this context, firstly, stationarity of the variables is examined in the recent study by ADF (Augmented Dickey Fuller), PP (Phillips-Perron), and KPSS (Kwiatkowski–Phillips–Schmidt–Shin) unit root tests. After the stationarity condition is met, the appropriate lag length in the VAR (Vector Autoregressive) analysis is determined. Following the lag length, requirements of the VAR model are checked. Then, the Granger Causality Test is applied to determine the causality relationships between variables. To investigate the response of a variable in the VAR model to a unit shock applied to another variable, the Impulse-Response Analysis is conducted. Finally, the Variance Decomposition Analysis, which shows the percentage of a change in variables explained by other variables, is performed.

In light of this framework, the results of the Unit Root Analysis are given in Table 1.

Table 1. Unit Root Tests

VARIABLE	ADF	PP	KPSS	REMARK
FOSİL	**1st Difference** -5.882908(0)[c] -2.621185(%1) -1.948886(%5) 1.611932(%10)	**1st Difference** -5.912193(3)[c] -2.621185(%1) -1.948886(%5) 1.611932(%10)	**Level** 0.114221(4)[b] 0.216000(%1) 0.146000(%5) 0.119000(%10)	**I(1)**
GDP	**Level** -6.361303(0)[a] -3.592462(%1) -2.931404(%5) 2.603944(%10)	**Level** -6.359012(3)[a] 3.592462(%1) -2.931404(%5) 2.603944(%10)	**Level** 0.068564(2)[a] 0.739000(%1) 0.463000(%5) 0.347000(%10)	**I(0)**
CO_2	**1st Difference** -9.804720(0)[c] -2.621185(%1) -1.948886(%5) 1.611932(%10)	**1st Difference** -10.02426(2)[c] -2.621185(%1) -1.948886(%5) 1.611932(%10)	**Level** 0.187734(4)[b] 0.216000(%1) 0.146000(%5) 0.119000(%10)	**I(1)**
YBİLİR	**Level** -3.633375(0)[b] -4.186481(%1) -3.518090(%5) 3.189732(%10)	**Level** -3.425600(4)[b] 4.186481(%1) -3.518090(%5) 3.189732(%10)	**Level** 0.161940(3)[b] 0.216000(%1) 0.146000(%5) 0.119000(%10)	**I(0)**

Note: The numbers in parentheses are the lag lengths determined by the SCI criterion in the ADF test. In the PP, KPSS, and NG-Perron tests, the Bartlett Kernel estimation method was used, and the bandwidth was determined as Newey-West. a: indicates that the regression includes a constant term, b: indicates that the regression includes a constant term and a trend, c: indicates that the regression does not include a constant term or a trend.

Source: Authors' own calculations

According to the ADF and PP test results of the variables FOSIL and CO_2 are stationary at first difference whereas KPSS results indicate that it is stationary at level. All test results show that GDP and YBILIR are stationary at level. Based on the unit root test results, it has been decided that the variables FOSIL and CO_2 are stationary at 1st difference I(1) and GDP and YBILIR are stationary at level I(0).

After unit root tests are performed in time series analysis, a VAR model is constructed.

Table 2. Lag Length According to Information Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-236.3475	NA	1.946257	12.01737	12.18626	12.07844
1	-125.0716	**194.7328***	**0.016695***	**7.253581***	**8.098020***	**7.558903***
2	-117.5475	11.66241	0.026179	7.677374	9.197365	8.226955
3	-99.54937	24.29745	0.025319	7.577468	9.773012	8.371308
4	-79.12801	23.48456	0.023170	7.356400	10.22750	8.394498

Source: Authors' own calculations

According to the information criteria given in Table 2, the most appropriate lag length has been determined as 1. Heteroskedasticiy, normality, autocorrelation, and stability of VAR(1) model are tested. The results are given in Table 3, 4, 5 and Figure 1, respectively.

Table 3. Heteroskedasticity Test Results

Chi-Sq. test stat.	df	Prob
86.84346	**80**	**0.2814**

Source: Authors' own calculations

Consequently, there is no changing variance and no serial correlation, residuals are normally distributed and all the inverse roots are in the unit circle, which implies the system is stable.

Table 4 Normality Test

Lag	Jarque-Bera	Prob
1	**0.678103**	**0.7124**
2	4.386279	0.1116
3	6.248453	0.044
4	0.716109	0.6990

Table 5 LM Autocorrelation Test Results

Lag	LM statistics	Prob
1	**14.17929**	**0.5854**
2	23.36141	0.1044
3	7.848333	0.9533
4	16.61897	0.4107

Source: Authors' own calculations

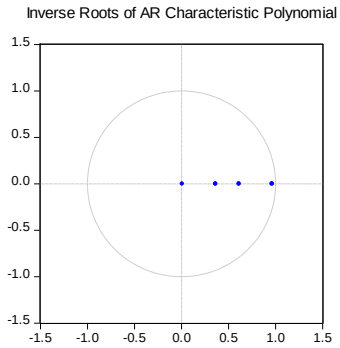

Figure 1. Inverse Roots for VAR Model
Source: Authors' own calculations

The Granger causality test is applied to determine the direction of causality between variables. Granger (1969) defines causality as "Y_t is causing X_t if we are better able to predict X_t using all available information than if the information apart from Y_t had been used."

Table 6. VAR Granger Causality

Dependent Variable: CO_2			**Dependent Variable: GDP**		
Independent Variables	Chi-Sq.	Prob.	Independent Variables	Chi-Sq.	Prob.
FOSIL	1.5707	0.2101	CO_2	0.0192	0.8899
GDP	0.0897	0.7646	FOSİL	0.0170	0.8964
YBİLİR	2.9599	0.0854	YBİLİR	0.0113	0.9152
Dependent Variable: FOSIL			**Dependent Variable: YBİLİR**		
Independent Variables	Chi-Sq.	Prob.	Independent Variables	Chi-Sq.	Prob.
CO_2	1.9318	0.1646	CO_2	1.0225	0.3119
GDP	0.3302	0.5655	FOSİL	0.6971	0.4038
YBİLİR	3.4012	0.0651	GDP	0.0002	0.9897

Source: Authors' own calculations

When Table 6 is examined, a unidirectional causal relationship from renewable energy sources to CO_2 density and non-renewable energy sources is obtained at a significance level of 10%.
Figure 2 displays the impulse – response analysis. The findings indicate that when a one standard deviation shock is given to renewable energy sources, the GDP growth response initially decreases, then increases, reaching the equilibrium point after the fourth period and following that it disappears. When a one standard deviation shock is given to CO_2 density, the GDP growth initially increases, then approaches the equilibrium point in the fourth period and later disappears. When a one standard deviation shock is given to fossil fuel energy consumption, the GDP growth initially decreases, then reaches the equilibrium point after the third period and then disappears. When a

one standard deviation shock is given to GDP growth, its negative effect on itself reaches the equilibrium point and gradually disappears after the second period.

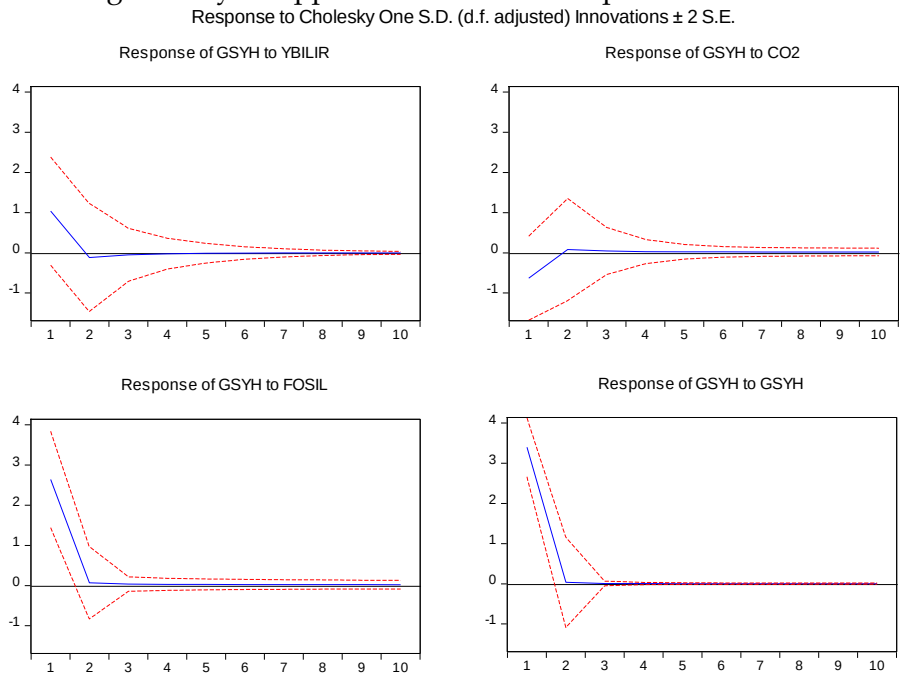

Figure 2. Impulse – Response Functions

Source: Authors' own calculations

Table 7 provides the results of the variance decomposition analysis for 10 periods. According to the results, in the first period, approximately 58% of the forecast error variance is explained by itself, while approximately 34% is explained by renewable energy sources, approximately 4% by fossil fuel energy consumption, and approximately 5% by CO_2 intensity. It is seen that the variance of the forecast error does not change much, and these ratios are approximately the same values for 10 periods.

Table 7. Variance Decomposition of GDP

Period	S.E	CO_2	FOSIL	GDP	YBILIR
1	0.069283	4.647738	3.640654	57.73324	33.97837
2	0.077356	4.677317	3.723687	57.66452	33.93447
3	0.080621	4.686137	3.742146	57.64742	33.92430
4	0.082584	4.689616	3.748345	57.64081	33.92122
5	0.084022	4.691763	3.751307	57.63665	33.92028
6	0.085194	4.693485	3.753163	57.63328	33.92007
7	0.086205	4.695026	3.754544	57.63028	33.92015
8	0.087104	4.696455	3.755675	57.62753	33.92034
9	0.087915	4.697793	3.756650	57.62499	33.92056
10	0.088652	4.699044	3.757517	57.62264	33.92080

Source: Authors' own calculations

Conclusion

Sustainable development is a strategy aimed at controlling and improving economic development, social equality, natural resource consumption, and social and healthy living while preserving the current and future quality of life. Many initiatives have been carried out to contribute to sustainable development, which has become the focus of attention after the "Limits to Growth" report (Meadows & Rome, 1972). These initiatives have taken place internationally and have created an action plan for sustainable development worldwide by drawing attention to the concept.

Energy consumption, which is an important input to economic activities, affects stability and sustainable development in many ways. Energy began to be used extensively with the beginning of the Industrial Revolution, and it has become one of the most important needs today with the

increasing demand. Therefore, it can be said that the development of countries is proportional to the expansion of energy sources. Renewable energy is defined as sustainable energy in terms of the environment and human health, while non-renewable energy consumption creates negative impacts on human life and nature. The utilization of sustainable energy sources plays a vital role in addressing the escalating environmental challenges linked to progress and growth.

In this study, time series analyses are used to investigate the impact of renewable and non-renewable energy sources and CO_2 emissions on sustainable development in Turkiye and to determine the relationship between them. Annual data covering the period from 1972 to 2015 is employed. VAR analysis, Granger causality test, impulse-response analysis, and variance decomposition analysis are performed in the paper. According to the Granger causality test, a unidirectional causality relationship from renewable energy sources variable to CO_2 intensity and fossil fuel energy consumption variables is obtained at 10% significance level.

When a shock of one unit is applied to all variables, the response of GDP growth variable is investigated by the Impulse-Response Analysis. The response of GDP growth to renewable energy sources is found to be positive whereas the response to CO_2 intensity and fossil fuel energy consumption is negative. This study shows that increasing the use of renewable energy sources will have a positive effect on sustainable development. Therefore, the use of renewable energy sources is necessary for addressing the increasing environmental problems associated with development. According to the variance decomposition analysis results, approximately 58% of the forecast error variance in the first period is accounted for by itself, while approximately 34% is accounted for by renewable energy sources, approximately 4% by fossil fuel energy consumption, and approximately 5% by CO_2 density. It was observed that the forecast error variance ratio did not change much over the 10 periods and during these periods the ratios remained approximately constant.

In conclusion, this study provides insights into the relationship between energy consumption and sustainable development in Turkiye. The findings highlight the importance of renewable energy sources in achieving sustainable development goals and the negative impact of fossil fuel energy consumption and CO_2 density on sustainable development.

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