

Araştırma Makalesi / Research Article

Determinants of Carbon Dioxide Emissions in the Organization of Turkic States: An Environmental Sustainability Perspective*

Ayşegül Baykul**

Selen Işık Maden***

Abstract

The ongoing climate crisis is one of the most severe threats to ecological, economic, and social development, affecting millions worldwide. Reducing greenhouse gas emissions is essential to limit the effects of the global climate crisis. This study aims to assess environmental sustainability by analyzing the impact of key determinants of carbon dioxide (CO₂) emissions in Azerbaijan, Kyrgyzstan, Kazakhstan, Uzbekistan, and Türkiye, the member states of the Organization of Turkic States. According to the results of the autoregressive distributed lag bounds test (ARDL), based on data covering the period 1997–2019, economic growth, energy use in agricultural productivity, and industrialization increase CO₂ emissions, whereas forest area reduces CO₂ emissions in the long run. The findings were evaluated for the aforementioned countries, and corresponding policy implications were presented.

Keywords

Organization of Turkic States, carbon dioxide emission, environment, renewable energy, sustainability.

* Date of Arrival: 11 April 2023 – Date of Acceptance: 08 March 2024

Citation: Baykul, Ayşegül, and Selen Işık Maden. "Determinants of Carbon Dioxide Emissions in the Organization of Turkic States: An Environmental Sustainability Perspective." *bilig*, no. 117, 2026, pp. 71-100, <https://doi.org/10.12995/bilig.7368>.

** Corresponding author; Assoc. Prof., Suleyman Demirel University, Faculty of Economics and Administrative Sciences, Department of Economics – Isparta/Türkiye, ORCID: 0000-0002-7581-9972, aysegulbaykul@sdu.edu.tr

*** Professor, Suleyman Demirel University, Faculty of Economics and Administrative Sciences, Department of Economics – Isparta/Türkiye, ORCID: 0000-0002-3998-855X, selenmeden@sdu.edu.tr

Çevresel Sürdürülebilirlik Açısından Türk Devletleri Teşkilatı Ülkelerinde Karbondioksit Emisyonlarını Etkileyen Faktörlerin Değerlendirilmesi*

Ayşegül Baykul**

Selen Işık Maden***

Öz

Devam eden iklim krizi dünya çapında milyonlarca insanı olumsuz etkileyen ekolojik, ekonomik ve sosyal kalkınmaya yönelik en ciddi tehditlerden biridir. Küresel iklim krizinin etkilerini sınırlamak için sera gazı emisyonlarının azaltılması önem arz etmektedir. Bu çalışmada Türk Devletleri Teşkilatına üye ülkeler olan Azerbaycan, Kırgızistan, Kazakistan, Özbekistan ve Türkiye'nin CO₂ (Karbondioksit) emisyonlarını belirleyen değişkenlerin etkisi araştırılarak, çevresel sürdürülebilirliğin değerlendirilmesi amaçlanmıştır. 1997-2019 dönemi verileri kullanılarak gerçekleştirilen çalışmada ARDL (Gecikmesi Dağıtılmış Otoregresif Sınır Testi) sonuçlarına göre, ekonomik büyüme ve tarımsal verimliliğin CO₂ emisyonlarını artırırken; yenilenebilir enerji kullanımı, sanayileşme ve orman alanlarının uzun dönemde CO₂ emisyonlarını azalttığı tespit edilmiştir. Elde edilen bulgular söz konusu ülkeler için tartışılarak politika çıkarımlarında bulunulmuştur.

Anahtar Kelimeler

Türk Devletleri Teşkilatı, karbondioksit emisyonu, çevre, yenilenebilir enerji, sürdürülebilirlik.

* Geliş Tarihi: 11 Nisan 2023 – Kabul Tarihi: 08 Mart 2024

Atf: Baykul, Ayşegül, ve Selen Işık Maden. "Determinants of Carbon Dioxide Emissions in the Organization of Turkic States: An Environmental Sustainability Perspective." *bilig*, no. 117, 2026, ss. 71-100, <https://doi.org/10.12995/bilig.7368>.

** Sorumlu yazar; Doç. Dr., Süleyman Demirel Üniversitesi, İİBF, İktisat Bölümü – Isparta/Türkiye, ORCID: 0000-0002-7581-9972, aysegulbaykul@sdu.edu.tr

***Prof. Dr., Süleyman Demirel Üniversitesi, İİBF, İktisat Bölümü – Isparta/Türkiye, ORCID: 0000-0002-3998-855X, selenmaden@sdu.edu.tr

Introduction

Climate change is one of the most serious threats to ecological, economic, and social development, adversely affecting millions of people worldwide. One of the key reasons for the increase in extreme weather phenomena observed in recent years is the rise in greenhouse gas emissions resulting from human activities. Numerous international agreements and policies have been enacted to limit greenhouse gas emissions. The steps taken in global climate policies, the first step of which was taken with the United Nations (UN) Framework Convention on Climate Change, expanded with the Kyoto Protocol, and finalized with the Paris Climate Agreement, are milestones on the path to combating the climate crisis. Differences of opinion regarding the measures to be taken to reduce greenhouse gas emissions constitute a major obstacle to effective climate action. As a result, underdeveloped countries, often referred to as the Global South, are disproportionately affected by the consequences of climate change. In this context, greenhouse gas emissions have increased significantly, particularly since the Industrial Revolution. These gases, which are seen as the cause of global warming, are also among the main causes of climate change. According to the Kyoto Protocol, the main gases contributing to the greenhouse effect are carbon dioxide (CO₂) with 77%, methane (CH₄) with 16%, nitrous oxide (N₂O) with 6%, and fluorinated gases—including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆)—which together account for approximately 1%. In this study, CO₂ emissions were used as the primary indicator of greenhouse gas emissions due to their dominant share.

The organized and systematic efforts of countries to address environmental problems date back to the 1970s. The first major international environmental conference organized under the auspices of the United Nations was the United Nations Conference on the Human Environment, held in Stockholm in 1972. One of the most significant outcomes of this conference was the establishment of the United Nations Environment Programme (UNEP). Moreover, the conference marked a turning point by initiating the development of national environmental legislation and related institutional structures in many countries. In the two decades leading up to the 1992 Rio Conference, the second major environmental summit

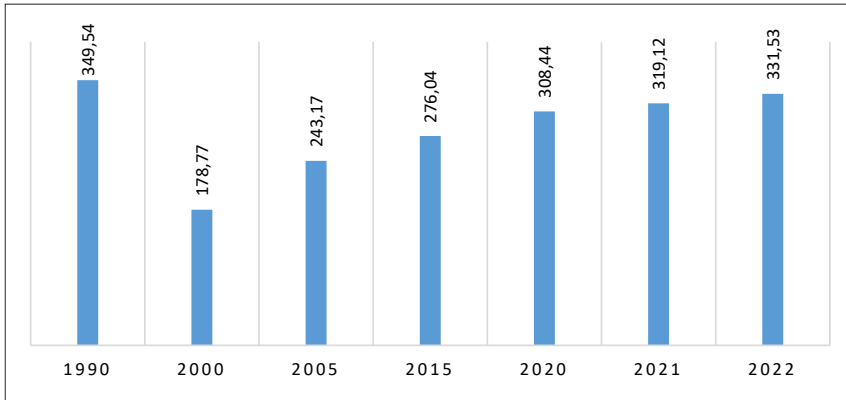
organized by the United Nations, environmental issues increasingly became part of the global policy agenda. The 1992 Rio Earth Summit underscored the intrinsic links between sustainable development, socio-economic progress, and environmental protection. Concurrently, the United Nations Framework Convention on Climate Change (UNFCCC) was opened for signature. As an extension of this framework, the Kyoto Protocol was adopted in 1997 with the primary objective of mitigating greenhouse gas emissions. However, following the initial commitment period spanning 2008 to 2012, the anticipated progress remained largely unfulfilled (Goldstein and Pevehouse 500-503), leading into the second commitment period from 2013 to 2020. During this interval, several key parties—specifically Australia, Canada, Japan, and Russia—formally declared their disinclination to undertake further binding commitments, thereby undermining the collective efficacy of the international climate regime. The protocol’s structural deficiencies are further compounded by a confluence of factors, most notably suboptimal participation rates, the reluctance of certain parties to assume binding emission reduction obligations, and the prohibitive fiscal implications associated with compliance. The global climate governance landscape underwent a transformative shift on December 12, 2015, with the unanimous adoption of the Paris Agreement by the parties to the UNFCCC. Serving as the successor to the Kyoto Protocol post-2020, this agreement represents a more comprehensive and universally ratified framework. Central to the implementation of the UNFCCC are the annual Conference of the Parties (COP) summits, among which COP26 in Glasgow stands as a critical juncture. Attended by 197 nations, COP26 was tasked with two primary mandates: maintaining the viability of the 1.5°C warming threshold—as delineated in the Nationally Determined Contributions (NDCs)—and mobilizing climate finance for developing economies. As the inaugural summit for evaluating post-Paris progress, COP26 paved the way for COP27 in Sharm El Sheikh (November 2022). The latter’s agenda was distinguished by a pivot toward climate justice, specifically through the establishment of loss and damage mechanisms to compensate vulnerable nations for the disproportionate impacts of climate-induced extreme weather events (Deloitte).

This study aims to evaluate the environmental sustainability of the Organization of Turkic States—specifically Azerbaijan, Kazakhstan, Kyrgyzstan, Türkiye,

and Uzbekistan—by examining the nexus between CO₂ emissions and key determinants, including economic growth, renewable energy consumption, urbanization, industrialization, agricultural productivity, and forest cover. To this end, the research first synthesizes the national policy frameworks and strategic documents aligned with each country's renewable energy potential and international climate commitments. Subsequent sections provide a comprehensive literature review and an empirical analysis of the variables influencing carbon emission trajectories across the member states.

Kazakhstan

Kazakhstan is the largest greenhouse gas emitter in Central Asia. According to Kazakhstan's national inventory report, greenhouse gas emissions in 2018 were 396 million tons of CO₂ equivalent. In 2013, the strategic policy document titled *Concept of Transition Towards Green Economy Until 2050* was developed and put into effect by the Ministry of Environmental Protection and the United Nations Development Program (UNDP). There are problems in the country such as inefficient use of resources, excessive deterioration of environmental standards, inadequacy of price and tariff systems for energy resources, and unsustainable use of natural resources. Developing policies on environmental issues is a necessity for the sustainability of the economy. The targets to be achieved over the years in the transition to a green economy have been determined with this plan. It is aimed to ensure the effectiveness of biological resources such as water and soil, modernize the existing infrastructure and develop new infrastructures, take profitable measures that reduce the environmental footprint to improve environmental quality, and take national security measures, including water supply. The estimated cost of transition to the green economy concept is estimated to be an average of 3–4 billion dollars annually by the end of 2050. These investments are planned to be provided with private investor funds. A large part of these investments will be used to ensure energy efficiency, develop renewable energy, and gas production infrastructure (REdiCAP 10–11). The chart below shows Kazakhstan's total greenhouse gas emissions in million tons of carbon dioxide equivalent between 1990 and 2022. The year in which emissions reached their lowest level was 2015. Despite the subsequent increase, a decrease of 5.15% is observed in 2022 compared to 1990.



Source: EDGAR

Figure 1. Kazakhstan Total Greenhouse Gas Emission (million tons CO₂ equivalent)

The Government of Kazakhstan presented the revised updated NDC document in June 2023. In its revised NDC, Kazakhstan has committed to a 25% reduction in carbon emissions by 2030, compared to 1990, depending on international support. The emission rate committed to reduction without external financial support is 15%. Adaptation components focusing on agriculture, water, forestry and disaster risk management have been added to the revised NDC document for the first time. In its NDC, Kazakhstan stated that it plans to expand adaptation measures to other sectors that are heavily affected by the negative effects of climate change, such as health and infrastructure. It also stated that it plans to present an updated draft of the Roadmap for NDC implementation between 2023 and 2024, focusing on long-term low-carbon development (NDC, “Kazakhstan”).

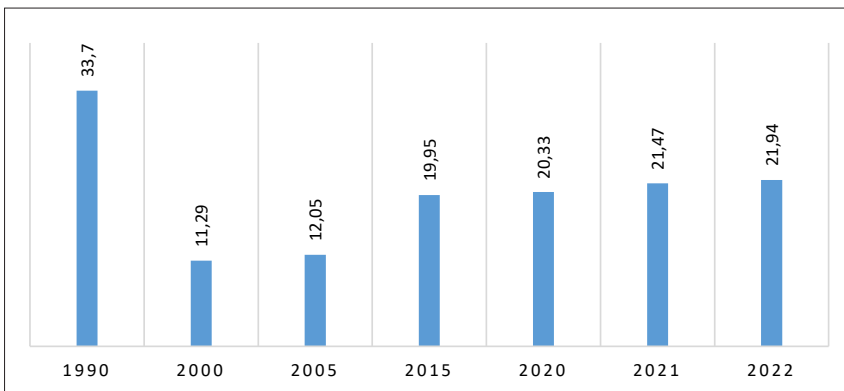
Kyrgyzstan

Kyrgyzstan is a landlocked, lower-middle-income country with a relatively low carbon footprint. The country has significant natural resources and great potential in terms of the agricultural sector, hydroelectric production and tourism industry. In its first NDC in 2016, Kyrgyzstan acknowledges that it is aware of the vulnerabilities to climate change and low greenhouse gas emissions per capita, but that there will be an increase in greenhouse gas emissions for planned economic development. In this NDC, it is aimed to reduce the greenhouse gas emissions committed by the country by 11.49%

– 13.75% by 2030, which is the first target period. It has been stated that these rates can be increased with an international support mechanism. In the long-term target period until 2050, an unconditional reduction between 12.67% and 15.69% is targeted. It is foreseen that this rate can be increased with international support. Considering the country’s goals under the Paris Agreement, Kyrgyzstan has not considered carbon pricing due to some lack of political will, lack of technical knowledge, and systematic failures (REdiCAP 11-12).

The government of Kyrgyzstan adopted the government program and related action plan on the development of the green economy in 2019. In this program, seven priority areas were determined, such as green energy, green agriculture, green industry, low-carbon and environmentally friendly transportation, sustainable tourism, waste management and green cities. In 2020, the Kyrgyz Government revised its existing structures and established the Green Economy and Climate Change Coordination Council in order to strengthen national coordination on climate change and green economy (UNDP).

The figure illustrates Kyrgyzstan’s aggregate greenhouse gas emissions, measured in millions of tons of carbon dioxide equivalent (MtCO₂e), for the period spanning 1990 to 2022. Emissions peaked in 1990 and reached their nadir in 2022. Despite a marginal upward trend following 2015, the data reveals a substantial 34.9% reduction in 2022 relative to 1990 levels.



Source: EDGAR

Figure 2. Kyrgyzstan Total Greenhouse Gas Emission (million tons CO₂ equivalent)

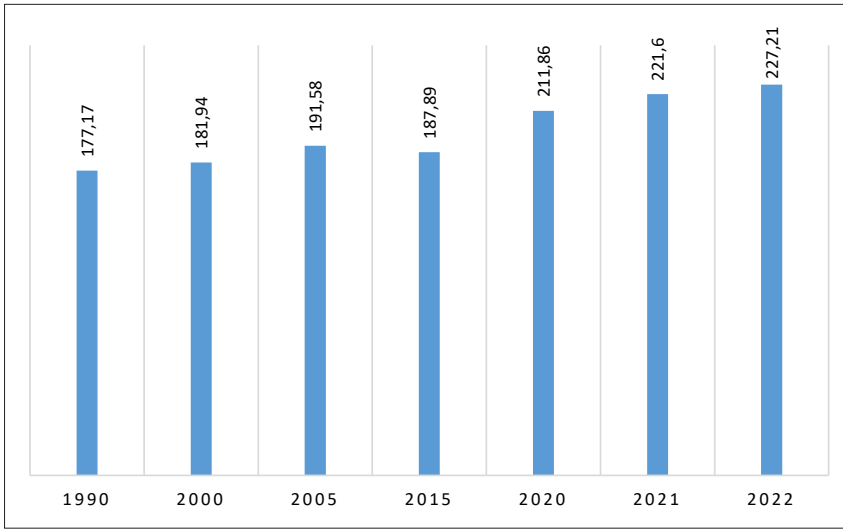
The Government of Kyrgyzstan presented the revised updated NDC document in October 2021. In this document, it set the conditional emission reduction target as 36.61% by 2025 and 43.62% by 2030. The unconditional emission reduction target is set as 16.63% by 2025 and 15.97% by 2030. This revised NDC also determined sectoral adaptation measures along with the qualitative targets to be achieved by 2025. The Kyrgyz government has also committed to revise its NDC in 2025 (NDC, “Kyrgyzstan”).

Uzbekistan

Uzbekistan signed the Paris Agreement in 2018. Most of the greenhouse gas emissions in Uzbekistan originate from the energy sector. The country also has the potential to use other renewable energies, particularly solar, wind and biomass energy. The Vision 2030 document includes important structural reforms regarding the environment. In this strategy, temporary targets have been determined to reduce energy dependency in the Gross Domestic Product (GDP) and to expand the use of renewable energy sources, especially solar energy. In this strategy, it is expected to reduce greenhouse gas emissions per GDP by 10% compared to 2010, increase energy efficiency, and increase their share in total electricity production by developing renewable energy sources. The World Bank included Uzbekistan in the group of countries most vulnerable to the negative effects of climate change. Uzbekistan has published a road map for a carbon-neutral electricity generation sector by 2050, with the support of the Ministry of Energy of Uzbekistan, the Ministry of Investment and Foreign Trade, the Government of Japan and a consortium of international experts and the support of the European Bank for Reconstruction and Development (EBRD). It is estimated that the investment need will be less than 2% of the annual GDP in the 2030-2050 period. Compared to financial costs, the expected benefits in terms of environmental impacts are greater. The government plans to end gas exports by 2025 as it believes it can achieve greater economic benefits, create jobs and attract investment by converting gas into more valuable products (REdiCAP 14-15).

In the figure below, Kyrgyzstan’s total greenhouse gas emissions in million tons of carbon dioxide equivalent between 1990 and 2022 are presented. It is observed that greenhouse gas, which was equivalent to 177.17 million

tons in 1990, increased until 2005, then started to increase again after 2020, after a slight decrease. It is seen that there is a 28.25% increase in greenhouse gas emissions in 2022 compared to 1990.



Kaynak: EDGAR

Figure 3. Uzbekistan Total Greenhouse Gas Emission (million tons CO₂ equivalent)

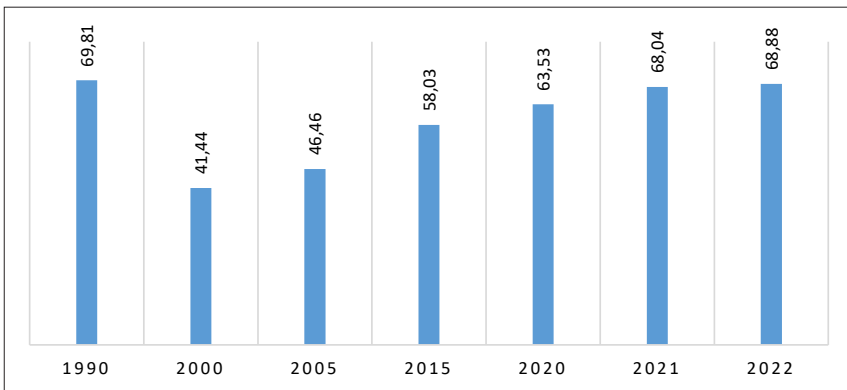
The Government of Uzbekistan presented the revised updated NDC document in October 2021. The Government of Uzbekistan has committed in this NDC to the target of reducing specific greenhouse gas emissions per unit of GDP by 35% below 2010 levels by 2030. This rate is considered an increase compared to the rate set at 10% in Uzbekistan's first NDC. In the revised 2021 NDC, the commitment to strengthen adaptation measures, especially in agriculture, is noteworthy. The government of Uzbekistan has stated that it will align its green economy transition strategy with its NDC by 2030 (NDC, "Uzbekistan").

Azerbaijan

Azerbaijan became a member of the UNFCCC in 1995 and ratified the Kyoto Protocol in 2000. In order to reduce greenhouse gas emissions and increase energy efficiency, the country prepared the state program for the use of State Alternative and Renewable Energy Sources Agency (SAARES) in

2004 and put it into effect in 2009. The country signed the Paris Agreement in 2016 and committed to reduce its greenhouse gas emission level by 35% in 2030 compared to 1990, which is considered the base year. The energy sector in Azerbaijan has an important place for the country's economy. Azerbaijan's new macroeconomic policy framework includes a shift towards sustainability and diversification in the medium – and long-term drivers of the economy. The Central Bank of Azerbaijan has implemented an action plan focusing on incorporating sustainability and climate risk into public and private financing mechanisms. This framework also complies with the Paris Agreement as well as national commitments to the United Nations' 2030 Agenda for Sustainable Development (EU4Climate). In Azerbaijan, the Islamic Development Bank supported the “waste to energy” project with a loan of 377.50 million euros to improve the ecological and sanitary conditions in the Greater Baku region, as well as to promote sustainable approaches in consumption and production (UN).

In the figure below, Azerbaijan's total greenhouse gas emissions in million tons of carbon dioxide equivalent between 1990 and 2022 are presented. The graph shows that Azerbaijan's greenhouse gas emissions were low between 1990 and 2000, showed an increase in 2005, and increased rapidly after 2015. Between 1990 and 2022, Azerbaijan's greenhouse gas emissions exhibited a marginal decline of approximately 1%.



Kaynak: EDGAR

Figure 4. Azerbaijan Total Greenhouse Gas Emission (million tons CO₂ equivalent)

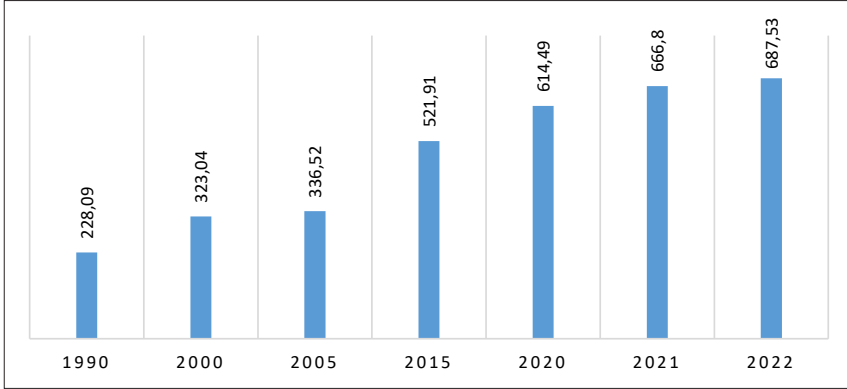
The Government of Azerbaijan presented the revised updated NDC document in October 2023. Azerbaijan's revised NDC commits to a 40% reduction in emissions by 2050 compared to 1990 levels, subject to international support. Sectors identified for mitigation measures include energy, industrial processes and product use, agriculture, land use, land use change, forestry, and waste management. The revised NDC also commits that the country will continue to plan and implement appropriate adaptation measures for particularly sensitive sectors such as agriculture (NDC, "Azerbaijan").

Türkiye

Türkiye became a party to the Kyoto Protocol in 2009. The National Climate Change Strategy Document, the country's main policy document on climate change, was prepared with the participation of public institutions, private sector representatives, non-governmental organizations and universities and was put into practice in 2010. Türkiye's Climate Change Adaptation Strategy and Action Plan (2011-2023), which is the first policy document on improving Türkiye's adaptation capacity to the effects of climate change, has identified five vulnerability areas across the country and defined extremely comprehensive targets and actions in these areas. These areas: i) water resources management, ii) agricultural sector and food security, iii) ecosystem services, biodiversity, and forestry, iv) natural disaster risk management and v) human health issues. Türkiye accepted the Paris Agreement in 2015, provided that its demand for access to financial and technology supports in the new climate regime was met. It signed the agreement on April 22, 2016, verbally stating that it is a developing country. However, the agreement entered into force in 2021 (Talu and Kocaman).

According to Türkiye's greenhouse gas inventory results, total greenhouse gas emissions in 2020 were calculated as 614.49 million tons (Mt) CO₂ equivalent (eq.), increasing by 3.1% compared to the previous year. Total greenhouse gas emissions per capita were calculated as 4 tons of CO₂ equivalent in 1990, 6.2 tons of CO₂ equivalent in 2019 and 6.3 tons of CO₂ equivalent in 2020. Of the total CO₂ emissions in 2020, 85.4% will come from the energy sector, 31.6% from electricity and heat production, 14.2% from the industrial processes and product use sector, and 0.4% from the agriculture and waste sectors (TUIK).

In the figure below, Türkiye's total greenhouse gas emissions in million tons of carbon dioxide equivalent between 1990 and 2022 are presented. It is seen that Türkiye's greenhouse gas emissions have been increasing continuously since 1990. It can be said that the increase rate will tend to decrease between 2020 and 2022. The increase between 1990 and 2022 is 201.4%.



Kaynak: EDGAR

Figure 5. Türkiye Total Greenhouse Gas Emission (million tons CO₂ equivalent)

Türkiye presented the revised updated NDC document in April 2023. In this NDC, Türkiye commits to reduce greenhouse gas emissions by 41% by 2030, accepting 2012 as the base year. Türkiye aims to peak its emissions by 2038 at the latest and reach net zero by 2053 (NDC, "Türkiye"). Türkiye's NDC has been aligned with the 12th National Development Plan prepared for the year 2024-2028.

Literature Review

The increase in demand for goods and services worldwide has also increased the demand for energy. Therefore, economic growth is thought to be driven primarily by energy. Non-renewable energy consumption is associated with a growth rate that deteriorates environmental quality. Economic growth is achieved through industrialization and trade liberalization, especially in many countries living below the poverty line. In the literature, the relationship between economic growth and CO₂ emissions has been investigated by academics for a long time. Holtz–Eakin, and Selden

investigated the link between economic growth per capita and CO₂ emissions per capita in the period 1951-1986 with panel data forecasting models. 130 countries were included in the study. In their research, they found that the marginal tendency towards CO₂ emissions decreased as a result of the development of economies. They stated that the Environmental Kuznets Curve (EKC) is in an inverted U shape. De Bruyn established a dynamic model that includes technological and structural change and energy intensity as well as the level of GDP. The study was tested with 34 years of data in 4 OECD (Organisation for Economic Co-operation and Development) countries (Netherlands, West Germany, UK and USA). As a result of the modeling, it was concluded that economic growth has a direct and positive effect on emissions. Yang examined the relationship between fossil fuels and energy consumption and GDP in Taiwan between 1954 and 1997. The study revealed that there is a bidirectional causality between total energy use and GDP. In their study for 52 countries between 1975 and 1990, Taskin and Zaim examined the connection between environmental efficiency, CO₂ emissions per capita and GDP per capita using non-parametric production frontier approaches. They found that the inverted U-shaped Kuznets curve is valid for countries with a GDP per capita of more than \$5000. Bengochea-Morancho et al. investigated the relationship between economic growth and CO₂ among industrialized countries and others. The study covers the years 1981-1995. As a result of the study, they found that CO₂ emissions are higher in industrialized countries. Based on the EKC hypothesis, Friedl and Getzner examined the link between economic development and CO₂ emissions in Austria for the period 1960-1999. This connection was evaluated by separating it into 2 periods. While an increase in CO₂ emissions was observed in direct proportion to economic growth in the 1960-1974 period; It was determined that the increase rate decreased in the period 1975-1999. In this context, it has been stated that the relationship between CO₂ and economic growth is N-shaped. In their study investigating the relationship between productivity increase and CO₂ emissions in the 1987-1996 period, Lo et al. concluded that there was a gap in the productivity increase trend with and without CO₂ emissions. Azomahou et al. examined the relationship between GDP and CO₂ for 100 countries in the period 1960-1996 with panel data analysis. He found that there is a positive and significant relationship between economic growth

and CO₂ emissions. Cialani tested the EKC hypothesis to examine the link between CO₂ emissions and income using data from 1861 to 2002 in Italy. The research showed that there was a positive link between CO₂ emissions and growth, but the inverted U shape of the EKC could not be confirmed. Halıcıoğlu examined the relationship between CO₂ emissions, income and foreign trade in Türkiye during the period 1960-2005. As a result of Granger causality tests, it was determined that there was a bidirectional relationship between income and CO₂ emissions in both the short and long term. Sharma investigated the determinants of CO₂ emissions for 69 countries between 1985 and 2005. It divided countries into subgroups based on income level. The study revealed that GDP per capita is one of the main determinants of CO₂ emissions. In their study with US data covering a 200-year period, Franklin and Ruth found that there was a continuous upward trend in CO₂ emissions per capita with economic growth. Jayanthakumaran et al. examined the relationship between CO₂ emissions, energy use, trade and income in China and India for the period 1971-2007 with the ARDL approach. It revealed that there is a positive relationship between CO₂ emissions and per capita income for China and India. Fuji and Managi analyzed the relationship between CO₂ emissions and economic growth in different industries in OECD countries for the period 1970-2005. They confirmed the EKC hypothesis in some sectors such as paper, wood and construction. Zhang and Wang examined the relationship between CO₂ emissions resulting from energy consumption and growth rates for Jiangsu Region in the period 1995-2019. They revealed that CO₂ emissions are closely related to rapid economic growth. Omri et al., in their study conducted in 54 countries for the period 1990-2011, investigated the causality relationship between panel data set and CO₂ emissions, foreign direct investment and economic growth. They identified a unidirectional causality relationship from CO₂ emissions to economic growth. Iqbal et al. investigated the impact of CO₂ emissions, renewable energy consumption, foreign direct investments and exports on economic growth in BRICS (Brazil, Russia, India, China, Republic of South Africa) countries with data for the period 2000-2018. As a result of the model estimation, they found that carbon emissions have a positive effect on economic growth in the long term. According to the causality results, it was stated that there is a bidirectional relationship between CO₂ emissions and economic growth.

Environmental economists and policy makers have emphasized the need to replace conventional energy consumption with renewable energy sources for sustainable economic growth. In recent years, renewable energy growth has been encouraged by government-supported projects such as tax breaks and grants. Thanks to cost competition, energy production costs have been reduced. In the scenario created by the International Energy Agency (IEA), the share of renewable energy in electricity production will increase by 39% in 2050 (production was 18.3% in 2002). Thus, reducing worldwide CO₂ emissions by 50% will reduce global temperatures by 2050. The literature on the rapid development of renewable energy and its impact on environmental quality and economic growth is quite rich (Al-Mulali et al.; Apergis and Payne; Moutinho and Robaina; Kahia et al.; Shahbaz et al., “The effect”). The results of empirical studies between renewable energy and CO₂ emissions are evaluated in three different groups. In the first group, there is a one-way causality relationship from renewable energy to CO₂ emissions (Apergis et al.; Zeb et al.; Jaforullah and King; Bilgili et al.; Bélaïd and Youssef), in the second group, there is a causality relationship from CO₂ to renewable energy (Menyah and Wolde – Rufael; Lin and Moubarak; Sebri and Ben-Salha), and the third group is the studies in which there is a bidirectional causality relationship (Apergis and Payne; Dogan and Seker; Jebli et al.). Urbanization and industrialization also have significant effects on CO₂ emissions. There is a rich literature showing the positive impact of these two variables on CO₂ emissions (Shahbaz et al., “Industrialization”; Li and Lin; Raheem and Ogebe; Liu and Bae; Mahmood et al.; Musa et al.; Mentel et al.; Sikder et al.). On the other hand, there are also studies suggesting that there is no significant relationship between urbanization and industrialization variables and CO₂ emissions (Hossain; Xu and Lin; Dong et al.). One of the variables that significantly affects CO₂ emissions is agricultural productivity. Rapid agricultural development and increased mechanization in agriculture are seen as one of the important factors that increase CO₂ emissions (Xiong et al.; Baumann et al.; Rehman et al.; Raihan, Li et al.; Wang et al.).

One of the main reasons why the global climate system has changed since the industrial revolution is the rapidly increasing CO₂ emissions resulting from deforestation and degradation of forest areas. The Intergovernmental Panel on Climate Change (IPCC) reported that land use, land use change

and forestry contribute approximately 17% of annual global greenhouse gas emissions. There are a limited number of studies in the literature that specifically investigate the dynamic effect between forest areas and CO₂ emissions. Begum et al. determined the dynamic effects of forestland on economic growth and CO₂ emissions in Malaysia between 1990 and 2016. Study findings showed that economic growth and deforested area have a negative impact on Malaysia's carbon emissions. Raihan and Tuspekova investigated the dynamic effects of economic growth, renewable energy use, urbanization, industrialization, tourism, agricultural productivity and forest areas on CO₂ emissions in Thailand with 1990-2019 data. As a result of the research, the coefficient of forest area is negative and significant, which means that increasing the forest area by 1% is associated with a 3.86% decrease in CO₂ emissions. Waheed et al. reported the negative effects of renewable energy use and forest area on CO₂ emissions in their study with 1990-2014 data in Pakistan. Using panel data from 86 different countries between 1990 and 2014, Parajuli et al. established a negative relationship between forest areas and CO₂ emissions.

Methodology

In this study, the dynamic effects of economic growth, renewable energy use, urbanization, industrialization, agricultural productivity, and forest areas on CO₂ emissions in the member countries of the Organization of Turkish States between 1997 and 2019 were investigated. The panel data set was created using World Bank Development Indicator Statistics. While CO₂ emissions were used as the dependent variable in the study, Economic growth, renewable energy use, urbanization, industrialization, agricultural productivity and forest area size were also used as explanatory variables. The table below lists the data used in the study.

Table 1
Variables and Descriptions

Variables	Unit	Description	Abbreviation
CO ₂	Kiloton (kt)	CO ₂ emission	LCO ₂
GDP	At constant 2015 prices, dollars	Gross Domestic Product	LGDP
RNE	% of total energy consumption	Renewable energy consumption	RNE
URB	% of population	Urbanization	URB
IND	At constant 2015 prices, dollars	Industrialization (including construction and value added)	LIND
AVA	% of GDP	Agricultural Productivity (Agriculture, forestry and fishing, added value)	AVA
FA	Km ²	Forest area	LFA

Logarithmic forms of variables other than % values were used in the model.

Empirical Model Design

The aim of the research is to determine and analyze the relationships between CO₂ and economic growth, renewable energy consumption, urbanization, industrialization, agricultural productivity, and forest areas in the countries within the scope of the study. As a result of the analysis, policy recommendations will be presented to ensure environmental sustainability by reducing carbon dioxide emissions.

Equation (1) shows the equation used in the analysis of the study.

$$LCO2_t = \alpha_0 + \alpha_1 LGDP_t + \alpha_2 RNE_t + \alpha_3 URB_t + \alpha_4 LIND_t + \alpha_5 AVA_t + \alpha_6 LFA_t + \epsilon_t \quad (1)$$

In the equation, α_0 and ϵ_t represent the constant and error terms, respectively, while α_1 , α_2 , α_3 , α_4 , α_5 and α_6 represent the coefficients.

Empirical Findings and Discussion

Cross-sectional dependence and homogeneity between variables are important in the selection of econometric tests such as unit root and cointegration tests used in the analysis. For this reason, first of all, the cross-sectional relationship between countries was tested in the study.

The results of the slope homogeneity/heterogeneity coefficient are shown in Table 2. According to Δ and $\hat{\Delta}$ test statistics, the null hypothesis “Slope parameters are homogeneous” is rejected at the 1% significance level. In other words, slope parameters vary between horizontal sections and are heterogeneous.

Table 2
 Slope Heterogeneity Test

	Pesaran and Yamagata		Slope Heterogeneity Test	
	Δ	$\hat{\Delta}$	Δ	$\hat{\Delta}$
$CO_2 = f(\text{GDP, RNE, URB, IND, AVA, FA})$	6.978*	8.640*		

p-values, * significance level 1%

Essentially, in panel data, cross-sectional dependence (CD) shows the spillover effects of a shock from one country to another. If the established model has a CD problem and is ignored, the results will lead to biased predictions (Pesaran). Therefore, Equation 1 was calculated using the Breusch-Pagan LM test, Pesaran CD test, and Pesaran scaled LM test, respectively. The results of all relevant tests are given in Table 3. The results show a strong rejection of the null hypothesis of “cross-section independence” (except for Pessary Scaled LM).

Table 3
 Cross Section Dependency Test Results

	Breusch-Pagan LM (t-stat)	Pesaran CD (t-stat)	Pesaran-Scaled LM (t-stat)
$CO_2 = f(\text{GDP, RNE, URB, IND, AVA, FA})$	31.75 (0.0004) *	8.659 (0.0000) *	0.1152 (0.9083) ***

p-values, */*** significance values respectively 1% and 10%

The CIPS (Cross-Section Augmented IPS) test, a second-generation unit root test developed by Pesaran et al., is used to test the unit root hypothesis in a panel data set containing both cross-sectional dependence and serial correlation. This test is performed by extending the IPS (Im, Pesaran and Shin) test by adding the cross-sectional means of the dependent variable and its first difference to the IPS test. Cross-sectional averages help control

for cross-sectional dependence in the panel data set and take into account this dependence, which can mislead unit root test results. The unit root hypothesis is rejected if the absolute value of the test statistic is greater than the critical values obtained from the appropriate distribution. The results of the CIPS test are described in Table 4. If the test statistics in absolute value are lower than their critical values, then the null hypothesis of non-stationarity is accepted. The findings show that urbanization and renewable energy are stagnant at the level; it has been shown that carbon dioxide emissions, economic growth, industrialization, agricultural productivity, and forest areas are stationary at first difference. As a result, panel ARDL is required to ensure the existence of a possible long-term relationship between the variables used in the empirical model. The ARDL test results are shown in Table 5.

Table 4
Second Generation Panel Unit Root Test (CIPS Testi)

	Level I(0)	1 st Difference I(1)
	Individual Intercept + Trend	Individual Intercept + Trend
CO ₂	-2.35017	-4.19275*
GDP	-2.53873	-4.57329*
RNE	-3.84302*	-4.91281*
URB	-3.71106*	-4.86231*
IND	-1.93907	-4.03662*
AVA	-1.44034	-5.29347*
FA	-1.87903	-3.72064*

p-values, */*** significance values respectively 1% and 10%, critical values respectively 1% and 5% -3.14 and -2.88

Table 5
 PMG Estimate of ARDL Model for CO₂ Emission

Variable	Long Term Estimation	
	Coefficient	Probability
GDP	1.5383	0.0013*
RNE	-0.0372	0.0000*
URB	0.0133	0.6431
IND	-0.7507	0.0014*
AVA	0.0261	0.0002*
FA	-8.2348	0.0000*
Short Term Estimation		
ΔGDP	-2.568	0.0265**
ΔRNE	-0.047	0.1864
ΔURB	0.818	0.1717
ΔIND	1.488	0.0084**
ΔAVA	-0.018	0.2775
ΔFA	4.2742	0.5409
ECM(-1)	-0.842000	0.0000*

p-values, significance values respectively 1% and 5%

In the equation considered within the scope of the study, except for urbanization and renewable energy use, I(0) and other variables are stationary at the first difference I(1).

In the study, ARDL results are given for both short and long term results. All long-term coefficients (except URB) were found to be statistically significant. It has been found that GDP and AVA increase CO₂, while RNE, IND and FA reduce CO₂ in the long term.

However, a 1% increase in FA, IND, RNE will reduce CO₂ by 8.23%, 0.75% and 0.03% respectively in the long run. The relationship between these three variables and CO₂ shows results consistent with the general trend, as evaluated in detail in the literature section. Increases in each variable will

have positive effects on reducing CO₂ emissions. A 1% increase in GDP and AVA will increase CO₂ by 1.54% and 0.03% respectively in the long run. If an increase in a country's national income increases CO₂ emissions in the long term but reduces CO₂ emissions in the short term, then a careful evaluation should be made in terms of the environment. Study findings regarding AVA are also compatible with the general trend in the literature. While GDP has a negative impact on CO₂ emissions in the short term, it creates CO₂ increasing effects in the long term. In the short term, a country can adopt environmentally friendly practices through economic growth, thereby reducing CO₂ emissions. However, in the long term, economic growth may increase consumption, transportation, and industrial activities, which may increase CO₂ emissions. Therefore, with the economic growth of a country, the adoption of environmentally friendly practices and environmental sustainability need to be taken into consideration. This could include practices such as investing in renewable energy sources, improving energy efficiency, reducing greenhouse gas emissions, promoting recycling and working towards sustainable development goals. As a result, a country's economic growth, along with adopting environmentally friendly practices in the short term, can increase CO₂ emissions in the long term. Therefore, adopting environmentally friendly practices and ensuring sustainability should be considered as an important part of economic growth. In the long run, GDP's increase in CO₂ emissions may be due to increased fossil fuel consumption. In this case, it can be said that the economies of the countries subject to the study are still dependent on fossil fuels. The share of fossil fuel energy consumption in the total energy consumption of the countries covered in the study as of 2013 is given respectively (98.21, 88.16, 72.21, 99.19, 97.74) (World Bank Database).

It is known that agricultural production activities, especially industrial agriculture, cause greenhouse gas emissions due to reasons such as intense energy consumption, fertilizer use and deforestation. This situation shows that the agricultural sector should be managed in a sustainable way. The agricultural sector plays a fundamental role in feeding the world population and ensures food security. However, it also causes negative effects on the environment. Therefore, the agricultural sector should adopt environmentally friendly practices and develop innovative solutions for sustainable agricultural management. These solutions include practices

that protect the environment, such as organic farming, sustainable farming techniques, the use of renewable energy and recycling agricultural waste.

The growth of forests can reduce the amount of carbon dioxide in the atmosphere. This shows that protecting and reforesting forest areas plays an important role in combating climate change. Forests not only absorb carbon but also provide other ecosystem services such as biodiversity, water cycling and preventing soil erosion.

Industrial activities can cause intense carbon emissions, especially in sectors such as energy, transportation and production. Therefore, the industrial sector must make intense efforts to protect the environment, especially in the short term. In the long term, innovations in the industrial sector, the use of environmentally friendly technologies, energy efficiency and the transition to renewable energy sources can reduce carbon emissions. However, this transformation process takes time, and increasing carbon emissions in the short term is the starting point of this process. Therefore, the industrial sector must adopt temporary solutions to protect the environment in the short term, such as energy efficiency, recycling and waste management. At the same time, investments should be made to transition to environmentally friendly technologies and renewable energy sources in the long term. As a result, when the added value of the industry is calculated as a percentage of its national income and it is determined that it increases carbon emissions in the short term but can reduce it in the long term, in this case, the industrial sector should try to protect the environment with temporary solutions in the short term and at the same time, efforts should be made to transition to environmentally friendly technologies in the long term.

If a country increases its share of energy production by using renewable energy sources, this can reduce CO₂ emissions in the long term. Therefore, the use of renewable energy sources is an important step towards sustainable development goals. Renewable energy sources produce less greenhouse gas emissions than fossil fuels and therefore help create a low-carbon energy sector. This helps slow climate change by reducing the concentration of CO₂ in the atmosphere. The use of renewable energy sources provides many advantages. For example, renewable energy sources can help increase local employment, ensure the security of energy supply and reduce energy bills. As a result, the use of renewable energy sources can contribute to

environmental sustainability by reducing CO₂ emissions in the long term. Therefore, it is important to invest in renewable energy sources, increase energy efficiency and work towards sustainable development goals.

Variables that are effective in the short term are IND and GDP. In the short term, a 1% increase in GDP will reduce CO₂ emissions by 2.6%, while a 1% increase in IND will increase CO₂ emissions by 1.49%.

Looking at the short-term analysis, the coefficient of the error correction term was also found to be negative and statistically significant (-0.84). This means that the short-term deviations between the series moving together in the long term disappear and the series converge to the long-term equilibrium value again. That is, the coefficient value of -0.84 means that approximately 0.84% of the deviations from long-term equilibrium are corrected in each period.

Conclusion

Azerbaijan, Kyrgyzstan, Kazakhstan, Uzbekistan and Türkiye, which are members of the Organization of Turkic States, have had significant impacts on economic growth, renewable energy use, urbanization, industrialization, agricultural productivity and CO₂ emissions of forest areas in recent years. The economic growth rate of these countries has been quite high in recent years. However, this growth also comes with environmental problems. However, the environmental awareness of these countries is increasing, and the use of renewable energy is becoming widespread.

In this study, the effects of factors affecting CO₂ emissions as environmental variables were examined. According to the long-term results obtained, it has been determined that economic growth and agricultural productivity variables increase CO₂ emissions. Economic growth and agricultural activities increase CO₂ emissions, making it difficult for governments to achieve sustainable development goals. Therefore, governments must adopt a range of policies and measures to reduce CO₂ emissions while maintaining economic growth and agricultural activities. One of these could be investing in renewable energy sources. Renewable energy sources can reduce CO₂ emissions by replacing fossil fuels. Governments can provide appropriate regulations, incentives, and tax breaks to encourage the use of renewable energy sources. Additionally, increasing energy efficiency is also an effective method to reduce CO₂ emissions. Governments can encourage the

insulation of buildings, the use of more efficient vehicles, and the adoption of energy-saving lighting systems to increase energy efficiency. There are many methods to reduce CO₂ emissions resulting from agricultural activities. For example, practices such as sustainable agricultural practices, organic farming, water management, and soil conservation can reduce CO₂ emissions. Governments can provide appropriate regulations and incentives to farmers to encourage these practices.

The study also found that the use of renewable energy resources, industrialization and forest areas reduce CO₂ emissions in the long term. These findings suggest that policy makers and decision makers should focus on these areas to ensure environmental sustainability. Additionally, this study can be used as an important source of guidance by showing the potential of renewable energy sources and forests when creating strategies to combat climate change. However, the use of renewable energy sources alone is not sufficient to reduce greenhouse gas emissions. Policymakers and industries need to take decisive action. These include increasing energy efficiency, phasing out fossil fuels and investing in carbon-neutral technologies. In conclusion, this study has shown that the use of renewable energy sources plays an important role in reducing CO₂ emissions. However, this alone is not enough, and policymakers and industries need to work together. Taking these steps will ensure significant progress in the fight against climate change. However, in the short-term analysis results, it was determined that industrialization increased CO₂. Since most of the energy used in the industrialization process is obtained from fossil fuels, it may cause CO₂ emissions to increase in the short term. For this reason, it is important not only to use more sustainable production methods in the industrialization process, but also to direct energy resources to renewable energy sources. In this case, it is recommended that governments support companies that apply sustainable production methods, save energy, and implement policies that reduce the use of fossil fuels.

Contribution Rate Statement

The authors' contribution rates in this study are equal.

Conflict of Interest Statement

There is no conflict of interest with any institution or person within the scope of this study. There is no conflict of interest between the authors.

References

- Al-Mulali, Usama, et al. "Estimating the Environment Kuznets Curve Hypothesis: Evidence from Latin America and the Caribbean Countries." *Renewable and Sustainable Energy Reviews*, vol. 50, 2015, pp. 918-924.
- Apergis, Nicholas, et al. "On the Causal Dynamics between Emissions, Nuclear Energy, Renewable Energy, and Economic Growth." *Ecological Economics*, vol. 69, no. 11, 2010, pp. 2255-2260.
- Apergis, Nicholas, and James E. Payne. "Renewable Energy, Output, CO2 Emissions, and Fossil Fuel Prices in Central America: Evidence from a Nonlinear Panel Smooth Transition Vector Error Correction." *Energy Economics*, vol. 42, 2014, pp. 226-232.
- Azomahou, Theophile, et al. "Economic Development and CO2 Emissions: A Nonparametric Panel Approach." *Journal of Public Economics*, vol. 90, no. 6-7, 2006, pp. 1347-1363.
- Baumann, Matthias, et al. "Carbon Emissions from Agricultural Expansion and Intensification in the Chaco." *Global Change Biology*, vol. 23, no.5, 2017, pp. 1902-1916.
- Begum, Rawshan Ara, et al. "Dynamic Impacts of Economic Growth and Forested Area on Carbon Dioxide Emissions in Malaysia." *Sustainability*, vol. 12, no. 22, 2020, <https://doi.org/10.3390/su12229375>.
- Bélaïd, Fateh, and Meriem Youssef. "Environmental Degradation, Renewable and Non-Renewable Electricity Consumption, and Economic Growth: Assessing the Evidence from Algeria." *Energy Policy*, vol. 102, 2017, pp. 277-287.
- Bengochea-Morancho, Aurelia, et al. "Economic Growth and CO2 Emissions in the European Union." *Environmental and Resource Economics*, vol. 19, 2001, pp. 165-172.
- Bilgili, Faik, et.al. "The Dynamic Impact of Renewable Energy Consumption on CO2 Emissions: A Revisited Environmental Kuznets Curve Approach." *Renewable and Sustainable Energy Reviews*, vol. 54, 2016, pp. 838-845.
- Cialani, Catia. "Economic Growth and Environmental Quality: An Econometric and a Decomposition Analysis." *Management of Environmental Quality: An International Journal*, vol. 18, no. 5, 2007, pp. 568-577.
- De Bruyn, Sander M. "Explaining the Environmental Kuznets Curve: Structural Change and International Agreements in Reducing Sulphur Emissions." *Environment and Development Economics*, vol. 2, no. 4, 1997, pp. 485-503
- Deloitte. "Cop206 Zirvesi Çıktıları." 24 August 2023, <https://www2.deloitte.com/content/dam/Deloitte/tr/Documents/risk/COP26-zirvesi-ciktilari.pdf>.

- Dogan, Eyup, and Fahri Seker. "Determinants of CO2 Emissions in the European Union: The Role of Renewable and Non-Renewable Energy." *Renewable Energy*, vol. 94, 2016, pp. 429-439.
- Dong, Feng, et al. "The Process of Peak CO2 Emissions in Developed Economies: A Perspective of Industrialization and Urbanization." *Resources, Conservation and Recycling*, vol. 141, 2019, pp. 61-75.
- EDGAR. "European Commission, Emissions Database for Global Atmospheric Research." 2023, https://edgar.jrc.ec.europa.eu/report_2023.
- EPA. "Global Greenhouse Gas Overview." 24 August 2023, <https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data>.
- EU4Climate. "Azerbaijan." 31 March 2023, <https://eu4climate.eu/azerbaijan/>.
- Franklin, Rachel S., and Matthias Ruth. "Growing Up and Cleaning Up: The Environmental Kuznets Curve Redux." *Applied Geography*, vol. 32, no. 1, 2012, pp. 29-39.
- Friedl, Birgit, and Michael Getzner. "Determinants of CO2 Emissions in a Small Open Economy." *Ecological Economics*, vol. 45, no. 1, 2003, pp. 133-148.
- Fujii, Hidemichi, and Shunsuke Managi. "Which Industry is Greener? An Empirical Study of Nine Industries in OECD Countries." *Energy Policy*, vol. 57, 2013, pp. 381-388.
- Goldstein, Joshua S., and John C. Pevehouse. *Uluslararası İlişkiler*. Trans. Özdemir, Haluk, Tarcan Matbaası, 2015.
- Halıcıoğlu, Ferda. "An Econometric Study of CO2 Emissions, Energy Consumption, Income and Foreign Trade in Türkiye." *Energy Policy*, vol. 37, no. 3, 2009, pp. 1156-1164.
- Holtz-Eakin, Douglas, and Thomas M. Selden. "Stoking the Fires? CO2 Emissions and Economic Growth." *Journal of Public Economics*, vol. 57, no. 1, 1995, pp. 85-10
- Hossain, Md Sharif. "Panel Estimation for CO2 Emissions, Energy Consumption, Economic Growth, Trade Openness and Urbanization Of Newly Industrialized Countries." *Energy Policy*, vol. 39, no. 11, 2011, pp. 6991-6999.
- Iqbal, Amir, et al. "Investigating the Nexus between CO2 Emissions, Renewable Energy Consumption, FDI, Exports and Economic Growth: Evidence from BRICS Countries." *Environment, Development and Sustainability*, vol. 25, no. 3, 2023, pp. 2234-2263.
- Im, Kyung So, M. Hashem Pesaran, and Yongcheol Shin. "Testing for Unit Roots in Heterogeneous Panels." *Journal of Econometrics*, vol. 115, no. 1, 2003, pp. 53-74.

- Jaforullah, Mohammad, and Alan King. "Does the Use of Renewable Energy Sources Mitigate CO2 Emissions? A Reassessment of the US Evidence." *Energy Economics*, vol. 49, 2015, pp. 711-717.
- Jayanthakumaran, Kankesu, et al. "CO2 Emissions, Energy Consumption, Trade and Income: A Comparative Analysis of China and India." *Energy Policy*, vol. 42, 2012, pp. 450-460.
- Jebli, Mehdi Ben, et al. "Testing Environmental Kuznets Curve Hypothesis: The Role of Renewable and Non-Renewable Energy Consumption and Trade in OECD Countries." *Ecological Indicators*, vol. 60, 2016, pp. 824-831.
- Kahia, Montassar, et al. "Impact of Renewable and Non-Renewable Energy Consumption on Economic Growth: New Evidence from the MENA Net Oil Exporting Countries (NOECs)." *Energy*, vol. 116, 2016, pp. 102-115.
- Li, Dongxue, et al. "Bio-straw Resource Recycling Systems: Agricultural Productivity and Green Development." *Resources, Conservation and Recycling*, vol. 190, 2023, <https://doi.org/10.1016/j.resconrec.2022.106844>.
- Li, Ke, and Boqiang Lin. "Impacts of Urbanization and Industrialization on Energy Consumption/CO2 Emissions: Does the Level of Development Matter?" *Renewable and Sustainable Energy Reviews*, vol. 52, 2015, pp. 1107-1122.
- Lin, Boqiang, and Mohamed Moubarak. "Renewable Energy Consumption–economic Growth Nexus for China." *Renewable and Sustainable Energy Reviews*, vol. 40, 2014, pp. 111-117.
- Liu, Xuyi, and Junghan Bae. "Urbanization and Industrialization Impact of CO2 Emissions in China." *Journal of Cleaner Production*, vol. 172, 2018, pp. 178-186.
- Lo, S. F., et al. "Taking CO2 Emissions into a Country's Productivity Change: The Asian Growth Experience." *The International Journal of Sustainable Development & World Ecology*, vol. 12, no. 3, 2025, pp. 279-290.
- Mahmood, Haider, et al. "Industrialization, Urbanization and CO2 Emissions in Saudi Arabia: Asymmetry Analysis." *Energy Reports*, vol. 6, 2020, pp. 1553-1560.
- Mentel, Urszula, et al. "Industrialization and CO2 Emissions in Sub-Saharan Africa: The Mitigating Role of Renewable Electricity." *Energies*, vol. 15, no. 3, 2022, <https://doi.org/10.3390/en15030946>.
- Menyah, Kojo, and Yemane Wolde-Rufael. "CO2 Emissions, Nuclear Energy, Renewable Energy and Economic Growth in the US." *Energy Policy*, vol. 38, no. 6, 2010, pp. 2911-2915.
- Moutinho, Victor, and Margarita Robaina. "Is the Share of Renewable Energy Sources Determining the CO2 kWh and Income Relation in Electricity Generation?" *Renewable and Sustainable Energy Reviews*, vol. 65, 2016, pp. 902-914.

- Musa, Kabiru Saidu, et al. "The Causality between Urbanization, Industrialization and CO₂ Emissions in Nigeria: Evidence from Toda and Yamamoto Approach." *Energy Economics Letters*, vol. 8, no. 1, 2021, pp. 1-14.
- NDC. "Azerbaijan." 2023, https://unfccc.int/sites/default/files/NDC/2023-10/Second%20NDC_Azerbaijan_ENG_Final%20%281%29.pdf.
- NDC "Kazakhstan." 2023, https://unfccc.int/sites/default/files/NDC/2023-06/12updated%20NDC%20KAZ_Gov%20Decree313_19042023_en_cover%20page.pdf.
- NDC. "Kyrgyzstan." 2023, <https://climatepromise.undp.org/what-we-do/where-we-work/kyrgyz-republic>.
- NDC. "Uzbekistan." 2023, <https://climatepromise.undp.org/what-we-do/where-we-work/uzbekistan>.
- NDC. "Türkiye." 2023, <https://climatepromise.undp.org/what-we-do/where-we-work/turkiye>.
- Omri, Anis, et al. "Causal Interactions between CO₂ Emissions, FDI, and Economic Growth: Evidence from Dynamic Simultaneous-Equation Models." *Economic Modelling*, vol. 42, 2014, pp. 382-389.
- Parajuli, Rajan, et al. "Incorporating Forests, Agriculture, and Energy Consumption in the Framework of the Environmental Kuznets Curve: A Dynamic Panel Data Approach." *Sustainability*, vol. 11, no. 9, 2019, <https://doi.org/10.3390/su11092688>.
- Pesaran, M. Hashem. "A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence." *Journal of Applied Econometrics*, vol. 22, no. 2, 2007, pp. 265-312.
- Pesaran, M. Hashem, and Takashi Yamagata. "Testing Slope Homogeneity in Large Panels." *Journal of Econometrics*, vol. 142, no. 1, 2008, pp. 50-93.
- Raheem, Ibrahim Dolapo, and Joseph O. Ogebe. "CO₂ Emissions, Urbanization and Industrialization: Evidence from a Direct and Indirect Heterogeneous Panel Analysis." *Management of Environmental Quality: An International Journal*, vol. 28, no. 6, 2017, pp. 851-867.
- Raihan, Asif, and Almagul Tuspekova. "Nexus between Economic Growth, Energy Use, Agricultural Productivity, and Carbon Dioxide Emissions: New Evidence from Nepal." *Energy Nexus*, vol. 7, 2022, <https://doi.org/10.1016/j.nexus.2022.100113>.
- REdiCAP. "Report from the Regional Dialogue on Carbon Pricing (REdiCAP) in Central Asia." 25-26 February 2021.
- Rehman, Abdul, et al. "Carbonization and Agricultural Productivity in Bhutan: Investigating the Impact of Crops Production, Fertilizer Usage, and

- Employment on CO₂ Emissions." *Journal of Cleaner Production*, vol. 375, 2022, 134178.
- Sebri, Maamar, and Ousama Ben-Salha. "On the Causal Dynamics between Economic Growth, Renewable Energy Consumption, CO₂ Emissions and Trade Openness: Fresh Evidence from BRICS Countries." *Renewable and Sustainable Energy Reviews*, vol. 39, 2014, pp. 14-23.
- Shahbaz, Muhammad, et al. "Industrialization, electricity Consumption and CO₂ Emissions in Bangladesh." *Renewable and Sustainable Energy Reviews*, vol. 31, 2014, pp. 575-586.
- Shahbaz, Muhammad, et al. "The Effect of Renewable Energy Consumption on Economic Growth: Evidence from the Renewable Energy Country Attractive Index." *Energy*, vol. 207, 2020, <https://doi.org/10.1016/j.energy.2020.118162>.
- Sharma, Susan Sunila. "Determinants of Carbon Dioxide Emissions: Empirical Evidence from 69 Countries." *Applied Energy*, vol. 88, no.1, 2011, pp. 376-382.
- Sikder, Mukut, et al. "The Integrated Impact of GDP Growth, Industrialization, Energy Use, And Urbanization on CO₂ Emissions in Developing Countries: Evidence From The Panel ARDL Approach." *Science of the Total Environment*, vol. 837, 2022, <https://doi.org/10.1016/j.scitotenv.2022.155795>.
- Talu, Nuran, and Habip Kocaman. "Türkiye'de İklim Değişikliği ile Mücadelede Politikalar, Yasal ve Kurumsal Yapı." 8 Nisan 2026, http://www.iklimin.org/egitimmateryalleri/TR%20Pol_NT.pdf.
- Taskin, Fatma, and Osman Zaim. "Searching for a Kuznets Curve in Environmental Efficiency Using Kernel Estimation." *Economics Letters*, vol. 68, no. 2, 2000, pp. 217-223.
- TÜİK. "Sera Gazı Emisyon İstatistikleri, 1990-2020." 23 August 2023, <https://data.tuik.gov.tr/Bulten/Index?p=Sera-Gazi-Emisyon-Istatistikleri-1990-2020-45862>.
- UNDP. "Partnership Actio on Green Economy." 2023, <https://www.undp.org/kyrgyzstan/projects/partnership-actions-green-economy>.
- Waheed, Rida, et al. "Forest, Agriculture, Renewable Energy, and CO₂ Emission." *Journal of Cleaner Production*, vol. 172, 2018, pp. 4231-4238.
- Wang, DanHui, et al. "Nexus between Agriculture Productivity and Carbon Emissions a Moderating Role of Transportation; Evidence from China." *Frontiers in Environmental Science*, vol. 10, 2023, <https://doi.org/10.3389/fenvs.2022.1065000>.
- Xiong, Chuanhe, et al. "The Relationship between Agricultural Carbon Emissions and Agricultural Economic Growth and Policy Recommendations of a

- Low-carbon Agriculture Economy.” *Polish Journal of Environmental Studies*, vol. 25, no. 5, 2016, pp. 2187-2195.
- Xu, Bin, and Boqiang Lin. “How Industrialization and Urbanization Process Impacts on CO2 Emissions in China: Evidence from nonparametric Additive Regression Models.” *Energy Economics*, vol. 48, 2015, pp. 188-202.
- Yang, Hao-Yen. “A Note on the Causal Relationship between Energy and GDP in Taiwan.” *Energy Economics*, vol. 22, no. 3, 2000, pp. 309-317.
- Zeb, Raheel, et al. “Causal Links between Renewable Energy, Environmental Degradation and Economic Growth in Selected SAARC Countries: Progress towards Green Economy.” *Renewable Energy*, vol. 71, 2014, pp. 123-132.
- Zhang, Ming, and Wenwen Wang. “Decouple Indicators on the CO2 Emission-economic Growth Linkage: The Jiangsu Province Case.” *Ecological Indicators*, vol. 32, 2013, pp. 239-244.