

Green Finance, Renewable Energy and Global Warming Relationship: Evidence From G20 Countries

Emine POLAT¹, & Erkan ALSU²

REFORMA

Year: 2025

Issue: 102

Research article

Received Date

20-11-2025

Accepted Date

22-12-2025

Please Cite As

Polat, E., & Alsu, E. (2025). Green Finance, Renewable Energy and Global Warming Relationship: Evidence From G20 Countries. *Reforma*, (102), 132-146.

Abstract

This study examines the relationship between green finance, renewable energy, and global warming. In this context, countries' carbon emission levels were selected as global warming indicators. The study included gross national product, renewable energy consumption, green investment level, and energy consumption as independent variables in the model. Using a panel data set covering the period 2009–2023, long-term relationships were analyzed using Panel FMOLS (Fully Modified Ordinary Least Squares) and Panel DOLS (Dynamic Ordinary Least Squares) techniques. The study found significant relationships among carbon emissions and green finance, energy consumption, renewable energy use, and gross national product. This study offers important policy recommendations for policymakers and stakeholders working in the field of environmental sustainability to combat climate change.

Keywords: Green finance, Renewable energy, Carbon emissions, Panel FMOLS - DOLS tests

Introduction

In recent years, drought, rising temperatures, and changing weather patterns have increased worldwide, posing a serious threat as global environmental issues (Wang and He, 2024:75-83). Although climate change is considered the most significant of these problems, others include air pollution, melting glaciers, rising sea levels, plastic pollution, overfishing, deforestation, agriculture and livestock farming, water and food insecurity, and textile waste. These problems, linked to the effects of human activities on nature, have gained momentum worldwide in terms of climate resilience. The main reason climate change is considered a global threat today is that greenhouse gas emissions from fossil fuel use have increased as a result of human activities. While greenhouse gases released into the atmosphere disrupt the environmental balance, the widespread use of fossil fuels since the industrial revolution has become a fundamental element in meeting increasing energy demands (Akın, 2021:28; Yılmaz et al. 2018:434-450). At this point, it has become imperative to take urgent and effective steps to protect the natural balance and reduce environmental problems, developing solutions and strategies accordingly.

Industrialization and its industrial extensions continue to be serious obstacles to global warming measures, directly and indirectly affecting many factors over time (Zengin and Yamaçlı, 2022:318). The initiation of labor-based power to create new living spaces during the transition from rural areas to city

¹ Doctoral - Gaziantep University, alincakemine2709@gmail.com, ORCID: 0009-0003-2504-1423

² Assoc. Prof. Dr. - Gaziantep University, Faculty of Economics and Administrative Sciences, Department of Business Administration erkanalsu@gmail.com, ORCID: 0000-0001-6102-1786



status has increased the use of fossil fuels in individual areas in most regions where industrial activities are carried out. Heating systems, which are increasingly used individually, and private transportation vehicles have also been factors that increase greenhouse gas emissions (Çokadar, 2020; Zengin and Yamaçlı, 2020:316-320).

The IPCC's (Intergovernmental Panel on Climate Change) recent session assessments on global warming and climate change have compared past and present temperatures. The published report highlights four key determinants related to current global warming. These determinants are, in order: the fact that current warming affects everywhere rather than just a specific region, the speed of warming, the intensity of warming, and the fact that climate conditions will approach an irreversible level if measures are not increased. While the average warming rate in the 19th and 20th centuries was 1.1 degrees, it is predicted that this temperature will increase to 1.5 degrees today (Akin, 2021:29-43; Hekimoğlu and Altındağ, 2008:2-6). Globally conscious measures must be taken against global warming, and the triggers of warming must be identified. One of the biggest triggers of global greenhouse gas emissions is energy production and consumption. The use of fossil fuels to meet energy needs releases carbon dioxide (CO₂), methane, and greenhouse gases. These gases trap heat in the atmosphere, causing global warming. Renewable energy sources (solar, wind, hydroelectric, geothermal, etc.), which do not produce direct carbon emissions during energy production, reduce carbon dioxide emissions by decreasing the use of fossil fuels. The widespread use of renewable energy sources not only slows down global warming but also provides advantages such as ensuring energy security and reducing energy costs (Attanayake et al., 2024).

Energy can be defined as the ability of a system to perform work. It is divided into two categories: fossil energy sources and renewable energy sources. Although fossil energy sources can only be used once, they have been the global energy source for years because they provide high energy in a short time (Jiakui et al., 2023). Environmental pollution caused by the unbalanced use of fossil fuels is now manifesting as global warming and poses a major risk to humanity (Kademli, 2020). The increase in the world's energy needs is leading to the depletion of fossil fuel reserves. This situation, along with the climate crisis, has accelerated research into alternative energy sources. Renewable energy sources are prioritized because they are environmentally friendly and renewable. Renewable energy sources include solar energy, wind energy, geothermal energy, hydraulic energy, and biomass energy (Yarımkaya, 2021).

Renewable energy sources (solar, wind, hydroelectric, geothermal, etc.) have emerged as an effective factor in addressing growing global concerns about environmental sustainability and climate change (Wei et al., 2023). Renewable energy sources such as solar, wind, hydroelectric, and geothermal, known as low-carbon energy technologies, have attracted significant interest (Liv et al., 2023). Renewable energy sources are cost-effective and do not harm the environment (Blazquez et al., 2020; Chen et al., 2022). The selected G20 countries examined in our study are among the ten countries with the highest global carbon emissions (the United States (US), China, Germany, Japan, the United Kingdom, France, Canada, Italy, India, and Turkey). These countries must transition from dirty energy to clean energy (Abeywickrama et al., 2024). The energy transition involves a conscious shift from fossil-based energy sources such as coal, oil, and natural gas to renewable energy sources such as solar energy, wind energy, geothermal energy, hydraulic energy, and biomass energy (Harichandan et al., 2022). Enabling the energy transition promotes resilient, equitable, and sustainable energy while also improving energy efficiency by reducing production costs (Newell, 2013:123-146). Therefore, the increasing global need for renewable energy is gaining momentum as a solution to the climate change problem (Lucas et al., 2021). High costs can be a major barrier to accessing renewable energy sources, especially for developing countries. This situation has given rise to green finance, which provides financial opportunities to individuals and institutions that support renewable energy sources in these countries (Doğanay and Çoşkun, 2020).

Green finance is a financial system and set of tools developed to support projects based on environmental sustainability. It is also a financial mechanism that provides funding for projects and investments aimed at preventing global warming and protecting nature by minimizing damage (Park and Kim, 2020). Green finance provides financial support for energy transition as well as for sustainable projects such as waste management, promoting environmentally friendly projects, and energy efficiency





(Kulsun and Hüda, 2018). Green bonds, green loans, sustainable investment funds, and environmental, social, and governance (ESG)-based financing instruments are the main components of this system. Green bonds, which have made significant progress in recent years, not only consider risk-return ratios for developed and developing countries but also contribute to environmental impacts by playing an active role in reducing carbon emissions (Renewable Energy Report, 2022). This allows investors to continue investing in low-risk assets while investing in environmentally friendly projects (Wang and Zhi, 2016:311-316). The goal is to strike a balance between economic growth and environmental protection, reduce carbon emissions, and accelerate the transition to clean energy.

Recent academic research shows that the role of green finance in the financial system is not limited to providing environmental benefits; it also offers advantages in terms of reducing investment costs, creating efficiency in resource allocation, and building confidence in capital markets (Zhao, Yue, and Wei, 2021). The implementation of sustainable finance in the banking sector enables the provision of credit at lower interest rates for environmentally friendly investments and facilitates the private sector's shift towards low-carbon production methods (Hamlaoui, 2025). Furthermore, green finance increases brand value and investor confidence by creating pressure on institutions to improve their environmental performance (Acca, 2024). This increases the financial appeal of sustainable projects and contributes to strengthening long-term economic stability with environmental responsibility principles.

Green finance is particularly critical in developing economies for expanding clean energy infrastructure, supporting renewable energy investments, and increasing green employment. In this respect, green finance is considered a comprehensive policy tool that combines both environmental and economic development goals (Tembelo and Özyeşil, 2024; Ma and Jiang, 2025).

The purpose of this study is to examine the relationship between green finance, renewable energy, and global warming. In recent years, green finance has gained significant attention worldwide as a means to combat the effects of global warming. Countries have increased their use of renewable energy sources to minimize the negative impacts of global warming and have begun to utilize green financial products and services to finance these sources. Bu bağlamda, sürekli artış gösteren karbondioksit (CO₂) emisyonları çalışmada bağımlı değişken olarak ele alınmış; yenilenebilir enerji tüketimi, kişi başına enerji kullanımı, sabit fiyatlarla gayri safi yurt içi hasıla (GSYİH) ve yeşil yatırımlar bağımsız değişkenler olarak analiz kapsamına alınmıştır. Thus, by understanding the relationships between the factors and their effects on CO₂ emissions, the aim is to empirically demonstrate the effectiveness of renewable energy use and green investments in reducing environmental pollution and to develop policies and strategies.

The remaining sections of the study include the national and international literature on the subject, the methodology used in the study, the data set used, the research findings, and finally the conclusions.

Literature Review

While studies on the relationship between carbon emissions and Gross Domestic Product have been extensively discussed in the literature, until the last 10 years, the number of studies examining the relationship between green finance and carbon emissions has been quite limited. However, in recent years, the relationship between green finance, renewable energy, and global warming has become a frequently discussed topic in the literature. For example, in a study by Muchiri et al. (2025), the relationship between green finance and carbon emissions was examined for 29 countries worldwide, concluding that green finance is effective in reducing carbon emissions and that this relationship remains independent for each country, regardless of other variables. Similarly, Zhang et al. (2025) examined the effect of green finance on carbon emission intensity in 251 Chinese provinces using panel data analysis and found that green finance significantly reduced carbon emission intensity and that this effect showed spatial spillover effects across provinces. Similar to these studies, Wu, Liu, and Cai (2025) examined the effect of green finance on carbon emission efficiency in specific Chinese cities using a panel threshold regression model and spatial panel data methods and concluded that increased use of green finance also significantly increased the carbon emission efficiency of cities. When examining studies that explore the relationship between global warming and renewable energy, Yang et al. (2024) examined the relationship between the performance of OECD countries in renewable energy indices and green bond financing using FMOLS and DOLS methods and concluded that green bond financing for





OECD countries has a predictable effect on renewable energy index variables. A similar study was conducted by Dong et al. (2023), which examined the role of renewable energy investment and geopolitical risk in green finance development for BRICS countries. The study found that increasing green finance by 0.05% could reduce environmental pollution through renewable energy investment and energy innovation, and that GPR shocks could affect green finance development in the long term. Similarly, Tang and Zhou (2023) examined the impact of green finance on renewable energy development from a spatiotemporal consistency perspective and concluded that green finance plays a role in renewable energy development in local and neighboring regions, and that the degree to which green finance affects renewable energy progresses gradually from local to neighboring regions. Studies show that the use of green finance has a positive effect on renewable energy. For example, Hou et al. (2023) examined the effect of green finance on renewable energy development using panel data and found that the development of green finance has positive effects on renewable energy development.

When examining the studies in the literature on the relationship between green finance, renewable energy, and global warming, it has been seen that green finance creates a predictable impact in the fight against global climate change by reducing carbon emissions (Yang et al. 2024; Sinha et al. 2023; Liong et al. 2023; Khaer and Anwar, 2022; Li et al. 2021; Charfeddine and Kahia, 2019). These studies prove the causal relationship between green finance support and increased use of renewable energy sources and CO2 emissions, which are the biggest source of global warming. However, it has been determined that the relationship between green finance and global warming has not been sufficiently examined. This study aims to fill this gap in the literature. Some of the studies in the literature are shown in the table below.

Journal	Author(s)and Year	Research Sample	Findings
Journal of Risk and Financial Management (JRFM)	Muchiri et al. (2025)	29 countries, 2018–2021	Green finance is effective in reducing carbon emissions; the relationship is consistent across countries.
Energy Economics	Zhang et al. (2025)	China (251 provinces), 2011–2022	Green finance reduces emission intensity; it has a spatial spillover effect.
Energy Policy	Wu, Liu & Cai (2025)	Chinese cities, 2006–2022	Green finance increases cities' carbon efficiency; green innovation strengthens this relationship.
Heliyon	Yang et al. (2024)	OECD countries, 2011–2019	Green bond financing positively affects the renewable energy index.
Technological Forecasting and Social Change	Dong et al. (2023)	BRICS countries, 2000–2020	Renewable energy investment and innovation increase green finance; geopolitical risks may be influential.
Renewable Energy	Tang & Zhou (2023)	China, 2010–2020	Green finance impacts renewable energy development in local and neighboring regions.
Environmental Science and Pollution Research	Hou et al. (2023)	53 countries (global), 2000	Green finance has a positive effect on renewable energy development.
Journal of Development Research	Rakshitha & Chaya (2023)	Global	Green banking projects reduce carbon emissions; they support sustainable development.
Sustainable Development	Udeggha & Muchapandwa (2023)	BRICS countries, 1990–2020	FinTech and green finance are effective in achieving carbon neutrality.
Renewable Energy	Wang et al. (2022)	E7 countries, 2000–2018	Green finance promotes the transition to renewable energy through R&D.
<i>Resources Policy</i>	Li et al. (2021)	China, 1990–2020	Causality in the direction of GDP → IRE → GFI; policies should encourage GFI and REEO investments.





Method

Empirical model and data

This study examines the relationship between green finance, renewable energy, and global warming. In this context, time series data for variables included in the model for selected G20 countries between 2009 and 2023 were analyzed using panel regression techniques. The reason for using data up to 2023 is that annual data for 2024-2025 has not yet been published. The data used in the empirical analysis, which employs a panel data econometric model, was obtained from the World Bank, OECD data, and IMF data databases. Annual data for the period 2009–2023 from 10 selected G20 countries, namely the United States (US), China, Germany, Japan, the United Kingdom, France, Canada, Italy, India, and Turkey, were used to examine the relationship between green finance, renewable energy, and global warming. The variables used in the analysis are, respectively: carbon dioxide emissions per capita (LNCO₂), gross domestic product per capita (LNGDP), green investment per capita (LNGINVT), energy consumption per capita (LNEU), and renewable energy consumption per capita (LNREC). The general equation of the panel model can be defined as follows:

$$CO2_{it} = \alpha_i + \beta_1 LNGINVT_{it} + \beta_2 LNEU_{it} + \beta_3 LNREC_{it} + \beta_4 LNGDP_{it} + \varepsilon_{it}$$

Here; $CO2_{it}$: carbon dioxide emissions per capita, $LNGINVT_{it}$ green investments, $LNEU_{it}$: energy consumption, $LNREC_{it}$ renewable energy consumption, $LNGDP_{it}$: economic growth (GDP), α_i : country fixed effect, ε_{it} error term. Here, i denotes the country, t denotes the time period.

The variables used in the model were converted to logarithmic form, and per capita values were considered to reduce scale differences between units.

Panel unit root tests

Before proceeding to cointegration analysis, it is necessary to determine the stationarity levels of the variables required from an econometric perspective. Panel unit root tests examine whether the series have a unit root and also test whether the panel has a unit root in general (Gujarati, 2003: 797-806). The Levin, Lin, Chu (LLC) and Im, Pesaran, and Shin (IPS) tests were used in this study. The LLC test, one of the first-generation panel unit root tests, was developed by Levin, Lin, and Chu (2002) to test whether the series in the panel data set are stationary. The LLC test assumes that all series (countries, firms, etc.) share a common autoregressive parameter. The LLC test, whose primary purpose is to test whether the series are stationary at the level, assumes a common unit root process for the series (Levin, Lin & Chu, 2002; Baltagi, 2008). The null hypothesis states that the series contain a unit root, while the alternative hypothesis states that the series are stationary. The LLC test model is as shown in the equation (Baltagi, 2008:240);

$$\Delta y_{it} = \rho y_{i,t-1} + \sum_{L=1}^i \theta_i \Delta y_{i,t-L} + a_{mi} d_{mt} + \varepsilon_{it} \quad m=1,2,3$$

d_{mt} , denotes the deterministic variable vector, a_{mi} $m=1,2,3$ denotes the corresponding coefficient vector, $d_{1t}=\{\text{empty set}\}$, $d_{2t}=\{1\}$ and $d_{3t}=\{1,t\}$ 'i.

It tests whether each series in the panel data set developed by Im, Pesaran, and Shin (2003) is stationary. The IPS test has a more flexible structure compared to the LLC test. (Baltagi, 2008; Im, Pesaran & Shin, 2003). The IPS test model is as shown in the equation;

$$\Delta y_{i,t} = \rho y_{i,t-1} + \varepsilon_{i,t} \quad , i=1,2,\dots,N, t=1,2,\dots,T.$$

$$H_0: \rho_i = 0 \quad \text{and} \quad H_1: \rho_i < 0 \quad , i=1,2,\dots,N.$$

The IPS test softens the assumption $\rho_1 = \rho_2 = \dots = \rho_N$ under the null hypothesis H_1 and essentially assumes a linear trend for each cross-sectional unit in the model. Based on the observations, this model, which can be tested for each cross-sectional unit, uses a separate unit root test for the horizontal sections without combining the data. The $t_{i,t}$ ($i=1,2,\dots,N$) shown in the equation represents the t-statistic for the unit root test (Maddala, 1999:365).



Panel cointegration tests

After examining the unit root test, cointegration analysis is performed to determine the existence of a long-term relationship between the series. In panel data analysis, the existence of a long-term relationship between variables is determined using cointegration tests. In this context, the panel cointegration tests developed by Pedroni (1999) and Kao (1999) were used in this study. The Pedroni test includes seven different cointegration tests to capture the within-panel effects. These effects within the cross-section are defined as within and between. The model used in the Pedroni (1999) test is shown below:

$$LNCO2_{it} = \lambda_i + \alpha_1 LNGDP_{it} + \alpha_2 LNGINVT_{it} + \alpha_3 LNEU_{it} + \alpha_4 LNREC_{it} + \varepsilon_{it}$$

[$LNCO2_{it}$: logarithmic value of carbon dioxide emissions, $LNGDP_{it}$ Logarithmic value of gross domestic product per capita, $LNGINVT_{it}$ Logarithmic value of green investment, $LNEU_{it}$ Logarithmic value of energy consumption, $LNREC_{it}$: Logarithmic value of renewable energy consumption, λ_i : Country-specific fixed effect, ε_{it} error term $i=1, \dots, N$: countries (selected 10 G20 countries), $t=2009, \dots, 2023$: represents the time dimension.

Another cointegration test to be used in the study is the Kao cointegration test, developed by Kao in 1999 using DF and ADF tests (Baltagi et al., 1999, pp. 814-823). Kao (1999) proposed modified Dickey-Fuller type test statistics that include coefficients between regressors, error terms, or serial correlations in the model (Hsiao, 2014:395). Unlike Pedroni, McCoskey and Kao proposed the Lagrange multiplier statistic with the null hypothesis of cointegration (Uçar, 2013:11). The Kao cointegration test model is as follows:

$$LNCO2_{it} = \beta_0 + \beta_1 \cdot LNGDP_{it} + \beta_2 \cdot LNGINVT_{it} + \beta_3 \cdot LNEU_{it} + \beta_4 \cdot LNREC_{it} + \hat{u}_{it}$$

\hat{u}_{it} It is a residual term obtained from the model and examines whether it is stationary in the Kao test. The second stage in the Kao test is tested with the following model:

$$\Delta \hat{U}_{it} = \rho \hat{u}_{i,t-1} + \sum_{p=1}^p \gamma^p \Delta u_{i,t} - \rho + e_{it}$$

In this equation, the Kao test examines whether the error terms \hat{U}_{it} contain a unit root.

If $\rho < 0$ and statistically significant, the error terms are stationary \rightarrow there is cointegration in the panel.

If $\rho = 0$ cannot be rejected, the error terms contain a unit root \rightarrow there is no cointegration.

Panel long run parameter estimates

After examining the long-term relationship between green finance, renewable energy, and global warming using Pedroni and Kao cointegration tests, the FMOLS (Fully Modified Ordinary Least Squares) method developed by Phillips and Hansen (1990) and the DOLS (Dynamic Ordinary Least Square) method developed by Stock and Watson (1993) were used to estimate the final unbiased coefficients of this relationship and to test the degree of consistency of the estimators within our expectations. The panel FMOLS model is as follows: $\beta_{GMOLS} = \frac{1}{N} \sum_{i=1}^N \beta_{FMOLS_i}$ represents the FMOLS coefficient estimated separately for each unit. In contrast, the t-statistic of the test is obtained as follows: $t_{\beta_{GMOLS}} = N^{-\frac{1}{2}} \sum_{i=1}^N t_{\beta_{FMOLS_i}}$. The DOLS method model, which solves the autocorrelation problem by adding lagged and forward difference terms to the regression equation, is as follows:

$$\begin{aligned} LNCO2_{it} = & \beta_{0i} + \beta_{1i} \cdot LNGDP_{it} + \beta_{2i} \cdot LNGINVT_{it} + \beta_{3i} \cdot LNEU_{it} + \beta_{4i} \cdot LNREC_{it} \\ & + \sum_{k=-K_i}^{K_i} \alpha_{ik} GDP_t + \sum_{k=-K_i}^{K_i} \delta_{ik} GINVT_t + \sum_{k=-K_i}^{K_i} \gamma_{ik} EU_t + \sum_{k=-K_i}^{K_i} \psi_{ik} REC_t \\ & + \varepsilon_{it} \end{aligned}$$



Here, K_i represents the number of lags and leads. The DOLS method combines the regression coefficients estimated separately for each country to arrive at average coefficients at the panel level: $\beta_{GDOLS} = \frac{1}{N} \sum_{i=1}^N \beta_{DOLS_i}$. Similarly, the t-statistic of the test is calculated as follows: $t_{\beta_{GDOLS}} = N^{-\frac{1}{2}} \sum_{i=1}^N t\beta_{DOLS_i}$.

Results

This study offers various contributions to improving green finance performance in selected G20 countries, which play a key role in achieving global climate action and sustainable development goals. It aims to reduce the effects of global warming by encouraging investments in renewable energy sources. In this regard, carbon dioxide (CO₂) emissions were considered as the dependent variable for the United States (US), China, Germany, Japan, the United Kingdom, France, Canada, Italy, India, and Turkey for the period 2009-2023. While renewable energy consumption, energy consumption per capita, gross domestic product (GDP) at constant prices, and green investments were included in the model as independent variables.

Table 1 provides information on the variables included in the model, while Table 2 provides information on the 10 countries included in the model.

Table 1. *Definition of Variables*

Variables	Explanation	Source
LNCO2	Logarithmic carbon emissions per capita (metric tons)	World Bank
LNEU	Logarithmic energy consumption per capita (petroleum equivalent kg per capita)	World Bank
LNGDP	Logarithmic gross national income per capita (US dollars)	World Bank
LNGINVT	Logarithmic green investment data (by country)	OECD data website
LNREC	Logarithmic per capita renewable energy consumption	World Bank

The panel regression equation for the study is shown in equation 1.1 below. $LCO_{2it} = \beta_{0it} + \beta_1 REC_{it} + \beta_2 EU_{it} + \beta_3 GDP_{it} + \beta_4 GI_{it} + u_{it}$ ($i=1, \dots, 10$) and ($t=2009, \dots, 2023$). In the equation, i represents countries, t represents time, and u represents the error term.

Table 2. *Selected Country Group from G20 Economies within the Scope of the Study*

Order	Country	Order	Country
1	United States	6	France
2	China	7	Canada
3	Germany	8	Italy
4	Japan	9	India
5	United Kingdom	10	Turkey



Table 3. Descriptive Statistics

	LNCO2	LNEU	LNGDP	LNGINVT	LNREC
Mean	6.92	7.98	28.79	13.85	2.56
Median	6.42	8.07	28.61	13.48	2.58
Maximum	9.44	9.01	30.67	16.26	3.62
Minimum	5.66	6.23	27.06	12.42	1.10
Standard Deviation	1.16	0.69	0.88	0.99	0.53
Skewness	0.88	-0.74	0.62	0.82	-0.24
Kurtosis	2.44	3.46	2.75	2.53	3.27
Jarque-Bera	18.31	12.76	8.66	15.52	1.66
Probability	0.00	0.00	0.01	0.00	0.44
Number of Obs.	129	129	129	129	129

Descriptive statistics for the variables used in the study are shown in Table 3 shows that for the selected G20 countries (United States (US), China, Germany, Japan, United Kingdom, France, Canada, Italy, India, and Turkey) for the variables LNCO2, LNGDP, LNGINVT, LNEU, and LNREC covering the years 2009-2023, the data with 129 observations include the mean, median, maximum and minimum values, standard deviation, skewness, kurtosis, and JB test. The table presents the results under these headings. LNGDP has the highest average value (28.78), indicating that the countries have high economic outputs. In this context, the panel is seen to be balanced.

The correlation matrix for the variables used in the study is shown in Table 4.

Table 4. Correlation Matrix Between Independent Variables

	LNCO2	LNEU	LNGDP	LNGINVT	LNREC
LNCO2	1	-0.062	0.807	0.953	-0.024
LNEU	-0.062	1	0.33	-0.17	-0.376
LNGDP	0.807	0.33	1	0.804	-0.357
LNGINVT	0.953	-0.17	0.804	1	0.005
LNREC	-0.024	-0.376	-0.357	0.005	1

The correlation matrix, which shows linear relationships between different variables, ranges from -1 to +1. Values close to +1 indicate a strong positive linear relationship between variables, meaning that as one increases, the other also increases. Values close to -1 indicate a strong negative linear relationship between variables, meaning that as one increases, the other decreases. Values close to 0 indicate a weak or no linear relationship between variables (Gujarati & Porter, 2009; Kennedy, 2008). When examining the linear relationships of the correlation matrix in terms of variables with the dependent variable LNCO2, it shows that there is generally no very high level of relationship between the variables, and therefore there is no serious multicollinearity problem in the model. This increases the reliability of the econometric model to be established and reveals that the variables can contribute to the model separately. Although strong relationships are observed only between some variables, the overall picture indicates a positive structure in terms of modeling.

Table 5. Unit Root Analysis Results for Variables

Variable	LLC				IPS			
	I(0)		I(1)		I(0)		I(1)	
	Cons	Cons+Trend	Cons	Cons+Trend	Cons	Cons+Trend	Cons	Cons+Trend
LNCO2	-1,248 0,106	-3,23 0,001***	-6,344 0,000***	-7,986 0,000***	2,174 0,985	-1,417 0,078*	-5,259 0,000***	-4,531 0,000***
LNEU	0,234 0,592	-282,3 0,002***	-803,1 0,000***	-432,3 0,000***	2,750 0,997	-164,9 0,049**	-889,9 0,000***	-606,1 0,000***
LNGDP	-567,6 0,000***	-443,5 0,000***	-805,8 0,000***	-122,6 0,000***	-0,680 0,248	-147,2 0,070*	-634,3 0,000***	-701,5 0,000***
LNGINVT	0,496 0,690*	-166,7 0,047**	-435,7 0,000***	-465,1 0,000***	4,086 1,000	-0,070 0,472	-418,9 0,000***	-204,6 0,020***
LNREC	-131,3 0,094*	-864,1 0,000***	-114,0 0,000***	-679,4 0,000***	0,422 0,663	-338,8 0,000***	-808,1 0,000***	-452,0 0,000***

***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.





As shown in Table 5 the results of the unit root test applied to the level values of the variables indicate that the t-statistics and probability results for the variables Inco2, Ingvnt, Ineu, Inrec, and Ingdp to be used in the analysis are not stationary at the [I (0)] level. When testing the stationarity of a series, if this series is stationary at the level, it is defined as [I (0)] in the econometric literature. It is not necessary to take the difference of this series. If a time series is stationary at the beginning without taking the difference, this series is integrated at the level. The deviations in the series are temporary, and the series tends to revert to its long-term mean (Tatoğlu, 2017). In our study, the series are not stationary at the level, and the difference of the series must be taken. If the series become stationary when the difference is taken, they are defined as [I(1)] first-order integrated (Enders, 2015).

As a result, Levin, Lin, and Chu; Im, Peseran, and Shin determined stationarity in the series using unit root tests. According to the findings, the series do not exhibit stationarity at the level. When the first differences were taken to make the series stationary, stationarity was achieved in the CO₂, GDP, GINVT, EU, and REC variables in the selected G20 countries. In other words, when the first differences of the variables were taken, it was concluded that they were first-order integrated variables that did not carry a unit root. Since the series are stationary at the first difference without taking the second difference, a panel cointegration analysis will be performed, enabling the modeling and estimation of the long-term relationship in the series.

Table 6. Results of Pedroni and Kao Cointegration Tests

Model:DLNCO ₂ =DLNEU+DLNGDP+DLNGINVT+DLNREC					
PEDRONI COINTEGRATION TEST RESULT					
	T-statistics	Possibility	Weighted statistic	t-	Possibility
Panel v-statistics	-0.324391	0.6272	-1.798262	0.9639	
Panelrho-statistics	1.825320	0.9660	2.083552	0.9814	
Panel PP-statistics	-1.666734	0.0478	-2.783757	0.0027	
PanelADF-statistics	-2.264277	0.0118	-4.746355	0.0000	
Panel v-statistics	-0.324391	0.6272	-1.798262	0.9639	
Panel rho-statistics	1.825320	0.9660	2.083552	0.9814	
Alternative hypothesis: individual AR coefs. (between-dimension)					
	T-statistics	Possibility			
Group rho-statistic	2.873497	0.9980			
Group PP-statistic	-3.497832	0.0002			
GroupADF-statistic	-3.119033	0.0009			
Group rho-statistic	2.873497	0.9980			
KAO COINTEGRATION RESULT					
	T-statistics	Possibility			
ADF	-7.231083	0.0000			
Residual variance	0.000411				
HAC variance	0.000477				

***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

As seen in Table 6, the Pedroni cointegration test for the long-term relationship between green finance, renewable energy, and global warming rejects the H₀ hypothesis (there is no cointegration between the series). Two of the panel test results are statistically significant at the 1% significance level, while the others are at the 5% and 10% levels. Among the group statistics, group PP and group ADF are statistically significant at the 1% significance level, and group rho is statistically significant at the 10% significance level. In the Pedroni cointegration test, which examines both panel and group statistics consisting of seven tests in general, it is observed that there is cointegration between the series in terms of probability significance. According to the Kao cointegration test, the H₀ hypothesis is rejected (there is no cointegration between the series). The ADF test result is statistically significant at the 1% significance level. The alternative hypothesis is accepted (there is cointegration between the series). It can be concluded that there is a significant relationship between green finance, renewable energy, and global warming in the long run. In this context, countries that invest in green finance have seen increased use of renewable energy resources and reduced negative impacts of global warming. Analysis reveals a long-term relationship between the variables.



**Table 7. FMOLS Analysis Results**

Variables	Coefficients	Standard error	t-statistic	Probability
LNEU	0.880440	0.037482	23.48976	0.0000
LNGDP	0.226479	0.026136	8.665517	0.0000
LNGINVT	-0.051959	0.014150	-3.671932	0.0004
LNREC	-0.129816	0.011477	-11.31125	0.0000
R-squared	0.999546			6.919550
Adjusted R-squared	0.999490			1.167956
S.E. of regression	0.026369			0.073011
Long-run variance	0.000109			

***, **, * indicate significance levels of 1%, 5%, and 10%, respectively

Panel FMOLS test results are shown in Table 7. When the panel FMOLS test results are evaluated on a panel basis, the coefficients are positive and statistically significant at the 1% significance level, as expected, with LNEU 0.88 and LNGDP 0.20, respectively. LNGINVT -0.05 and LNREC -0.12, respectively, are negative and statistically significant at the 1% significance level. In other words, a 1% change in the LNEU and LNGDP variables has a positive effect on carbon emissions in the long term, with ratios of 0.88 and 0.20, respectively. A 1% change in the LNGINVT variable is said to cause a -0.05 decrease in carbon emissions. In other words, an increase in the LNGINVT variable reduces carbon emissions. An inverse relationship is observed between them.

Table 8. DOLS Analysis Results

Variables	Coefficients	Standard error	t-statistic	Probability
LNEU	0.959598	0.094928	10.10872	0.0000
LNGDP	0.203046	0.060899	3.334148	0.0014
LNGINVT	-0.055703	0.033015	-1.687212	0.0964
LNREC	-0.128911	0.035607	-3.620409	0.0006
R-squared	0.999745			6.919550
Adjusted R-squared	0.999537			1.167956
S.E. of regression	0.025141			0.041084
Long-run variance	0.000460			

***, **, * indicate significance levels of 1%, 5%, and 10%, respectively

Panel DOLS test results are shown in Table 8. When the panel DOLS test results are evaluated on a panel basis, the coefficients are positive and statistically significant at the 1% significance level, as expected, with LNEU 0.95 and LNGDP 0.20, respectively. LNGINVT -0.05 and LNREC -0.12 are negative and statistically significant at the 10% and 1% significance levels, respectively. In other words, a 1% change in the LNEU and LNGDP variables is said to have a positive effect on carbon emissions in the long term, with ratios of 0.95 and 0.20. A 1% change in the LNGINVT variable is said to cause a -0.05 decrease in carbon emissions. In other words, an increase in the LNGINVT variable is observed to reduce carbon emissions.

Conclusion

Green finance provides financial support for investments in projects that promote environmental sustainability. In other words, it encompasses a set of mechanisms that provide financial support to encourage projects and investments that provide environmental benefits, such as energy efficiency, renewable energy production, carbon emission reduction, waste management, and biodiversity conservation (OECD, 2017). The increasing focus on green finance by national and international financial institutions, governments, and the private sector to combat global warming, generate renewable energy resources, and achieve sustainable goals is increasing the importance of practices in this area (World Bank, 2020).

This research uses data from reliable sources to analyze variables such as carbon emissions, energy consumption, income levels (GDP), green investments, and renewable energy consumption for selected G20 countries. The empirical relationship between green finance, renewable energy, and global warming was examined through panel data analysis. Similar studies conducted in previous years have yielded varying results due to the different year intervals and variables included in the study.





For example, Xu et al. (2023) examined the relationship between green finance, renewable energy, and carbon emissions in selected Asian countries. The study investigated the dynamic correlation between non-fossil fuel and fossil-based energy use, economic growth, and Gross Domestic Product (GDP) variables in 10 selected Asian countries. The study used the Common Correlated Effects Average Group (CCEMG) method, using data from 1995 to 2018. Empirical findings indicate a balance between the variables in the long run. They concluded that a 1% increase in renewable energy consumption would reduce carbon dioxide emissions by 1.15%, indicating the necessity of green finance for the transition to a more sustainable energy economy. Liza et al. (2024) summarized and assessed the effects of renewable energy investments, particularly in green sources, geopolitical risk, economic growth, foreign direct investment, and gross capital formation on carbon emissions in G20 countries. The study evaluated data between 2000 and 2022 using the CUP-FM (Continuously Updated Fully Modified) and CUP-BC (Continuously User Bias Correction) methods. The study found a negative correlation between renewable energy investment, green finance, and carbon emissions in the long run, while foreign direct investment, gross capital formation, GDP growth, and geopolitical risk were positively correlated with CO2 emissions.

Li et al. (2021) examined the causal link between renewable energy investment (IRE), green finance (GFI), economic growth (GDP), renewable energy electricity generation (REEO), and private participation energy investment (EIPP) for China, covering the 1990-2020 time series data. The study found that of the five variables used, IRE, REEO, and GFI were the most variable, with causal relationships extending unidirectionally from GDP to IRE and from IRE to GFI. The relationship between these variables varied in the short and long term, and a link was observed between EIPP and IRE. Dong et al. (2023) examined the role of geopolitical risk and renewable energy investments on the development of green finance within the BRICS countries. The study considered green finance, economic growth, green credit, geopolitical risk (GPR), environmental sustainability, and renewable energy investments as variables; analyses for the period 2000–2020 were conducted cross-sectionally using an augmented distributed lag model (CS-ARDL). The findings reveal that a 0.05% increase in renewable energy investments and energy innovation within the framework of green finance can contribute to reducing environmental pollution, and that geopolitical risk shocks can affect the development of green finance in the long term.

The results of this study differ from previous studies due to differences in the variables used and country groups. Furthermore, the year intervals used in the study also differ. The study's descriptive statistics, standard deviation in the correlation matrix between variables, skewness and kurtosis, JB and mean coefficients, and the number of observations differ from previous studies. An examination of the correlation relationship between independent variables reveals that there is no very high level of correlation between the variables, and therefore, there is no multicollinearity problem in the model. Therefore, the fact that the variables can contribute individually to the model indicates a positive modeling structure. The unit root stationarity test indicates that all variables in question are stationary in the first difference, and the unit root properties are rejected. The results of the Pedroni and Kao cointegration tests examining the relationship between carbon emissions and green finance, renewable energy consumption, and gross domestic product energy consumption indicate that hypothesis H0 (no cointegration between the series) is rejected. Two of the panel statistics are statistically significant at the 1% significance level, while the other two are statistically significant at the 5% and 10% significance levels. Of the test statistics, Group PP and Group ADF are statistically significant at the 1% significance level, and Group rho is statistically significant at the 10% significance level. The Pedroni cointegration test, which examines both panel and group statistics consisting of seven tests in general, reveals cointegration between the series at a probability significance level. According to the Kao cointegration test, hypothesis H0 (no cointegration between the series) is rejected. The ADF test statistic is statistically significant at the 1% significance level. The alternative hypothesis (cointegration between the series) is accepted. It is concluded that there is a significant relationship between green finance, renewable energy, and global warming in the long run.

The relationship between green finance, renewable energy, and global warming in selected G20 countries exhibits a long-term co-movement according to the Pedroni and Kao cointegration estimation results, and the analyses indicate a long-term relationship between the variables. Following the Pedroni





and Kao cointegration estimation tests, FMOLS (Fully Modified Ordinary Least Squares) and DOLS (Dynamic Ordinary Least Square) methods were used to estimate the final unbiased coefficients of this relationship and to test the consistency of the estimators within our expectations. According to the panel FMOLS results, the coefficients are positively signed and statistically significant at the 1% significance level; the estimated coefficients for LNEU and LNGDP are 0.88 and 0.20, respectively. The coefficients were negative and statistically significant at the 1% significance level, with LNGINV-0.05 and LNREC -0.12. In other words, in the long run, a 1% change in the LNEU and LNGDP variables is said to have a positive impact on carbon emissions, with ratios of 0.88 and 0.20, respectively. A 1% change in the LNGINVT variable is said to cause a -0.05 decrease in carbon emissions. In other words, an increase in the LNGINVT variable reduces carbon emissions. An inverse relationship is observed between them.

When the panel DOLS test results are evaluated on a panel basis, the coefficients are positive and statistically significant at the 1% significance level, as expected, for LNEU 0.95 and LNGDP 0.20, respectively. They are negative and statistically significant at the 1% and 1% significance levels, respectively, for LNGINVT -0.05 and LNREC -0.12. In other words, in the long term, a 1% change in the LNEU and LNGDP variables is said to have a positive effect on carbon emissions, with coefficients of 0.95 and 0.20. A 1% change in the LNGINVT variable is said to cause a -0.05 decrease in carbon emissions. In other words, an increase in the LNGINVT variable appears to reduce carbon emissions. In general, in both models, energy consumption and economic growth tend to increase emissions, while renewable energy and green investments tend to reduce carbon emissions. In this regard, the need to move away from carbon-intensive energy sources and promote energy efficiency, increase environmental regulations and projects integrated into the economic growth process, increase investment in renewable energy sources to support both emission reduction and energy security, and increase and effectively monitor green financing instruments play a critical role in the transition to a low-carbon economy.

In light of the analysis results, policymakers and those combating the climate crisis offer the following recommendations to individuals and institutions transitioning from non-renewable energy sources to renewable energy, and to those utilizing green financing tools, one of the first steps in combating the global climate crisis: Although the global climate crisis has been addressed in both developed and developing countries for the past three decades, a definitive solution has not been reached. Carbon dioxide emissions, fueled by the burning of fossil fuels, are continuously increasing, highlighting the need for urgent action. The selected G20 countries examined in our study account for 85% of global gross domestic product and 80% of energy-related carbon emissions. It is imperative that these countries reduce their carbon emissions. Green financing, gross domestic product, energy use, and renewable energy use will lead to significant changes in CO₂ emissions. First, this study demonstrates econometrically that renewable energy consumption has a long-term reducing effect on carbon emissions. To support the sustainable energy transition and increase the share of renewable resources in selected G20 countries, it is necessary to turn to green finance, which provides financial support for these projects. Green finance, which has a wide range of applications, is particularly effective in global climate action, including energy, construction, transportation, water management, and waste management.

Green finance is critical for developing environmentally friendly policies and sustainable development goals. Secondly, selected G20 countries account for a large portion of global energy demand. This increases carbon emissions and hinders the achievement of climate targets. Our study demonstrates econometrically that energy consumption has a long-term increasing impact on carbon emissions. To reduce the dominance of fossil fuels in energy supply, the transition to renewable energy sources must be accelerated. To reduce overall energy consumption and increase energy efficiency, energy-intensive sectors should be supported with green finance to transition to low-emission production.

The selected G20 countries included in our study, which are responsible for a significant portion of global energy consumption and carbon emissions, are responsible for a significant portion of global energy consumption and carbon emissions. Thirdly, green financing mechanisms should be expanded to finance projects that will reduce fossil fuel dependency in these countries. In combating carbon emissions, green financing is not only a means of providing capital but also a policy tool that enables





the dissemination of environmentally friendly technologies and the implementation of low-carbon development goals. The use of green financing instruments, along with the adoption of performance criteria based on carbon reduction, will increase environmental efficiency and prevent resource waste. Therefore, for decision-makers seeking to limit carbon emissions and achieve a sustainable environmental transformation, green financing must be structured in an effective, traceable, and incentivized manner. The findings of the study suggest that integrating green financing policies not only with environmental but also with economic and social dimensions will play a significant role in helping countries achieve their climate goals. The current study is subject to several limitations. Initially, although the study focused solely on carbon emissions, other gases such as greenhouse gases, ozone, nitrogen oxides, and sulfur dioxide emissions are also significant problems in environmental degradation. Therefore, examining other harmful gases would be beneficial in future studies. To more comprehensively assess the impact of green finance on renewable energy and global warming, incorporating structural and institutional variables such as environmental taxes, governance quality, financial development, energy efficiency, and green innovation indicators into the model would be more beneficial and provide insights into different indicators

Ethical Declaration

During the writing process of the study “*Green Finance, Renewable Energy and Global Warming Relationship: Evidence From G20 Countries*” scientific rules, ethical and citation rules were followed. No falsification was made on the collected data and this study was not sent to any other academic publication medium for evaluation.

Statement of Contribution Rate of Researchers

The contribution rates of the authors in the study are equal.

Declaration of Conflict

There is no potential conflict of interest in the study.

Notes

This article is derived from the doctoral dissertation of Emine Polat, a doctoral student in the Department of Business Administration at Gaziantep University's Faculty of Economics and Administrative Sciences.

References

- Acca. (2024). What is green finance / Advantages of green finance. ACCA Global. <https://www.accaglobal.com>
- Akın, F. N. (2021, 2 Kasım). Küresel iklim değişikliği hakkında en çok merak edilenler. Bilim Teknik TÜBİTAK. <https://bilimteknik.tubitak.gov.tr/makale/kuresel-iklim-degisikligi>
- Alanlar, F. (2018). Yeniden düşünmek: Yeşil bankacılık modeli içinde Bangladeş örneği. *The Günlük*, 52(2), 197–214.
- Attanayake, A. M. W. K. L., Jayasinghe, S. D., & Rathnayake, R. M. U. S. (2024). Renewable energy as a solution to climate change. *Environmental Challenges*, 12, 100948. <https://doi.org/10.1016/j.envc.2023.100948>
- Baltagi, B. H. (2008). *Econometric analysis of panel data* (4th ed.). John Wiley & Sons.
- Charfeddine, L., & Kahia, M. (2019). Impact of renewable energy consumption and financial development on CO₂ emissions and economic growth in the MENA region: A panel vector autoregressive (PVAR) analysis. *Renewable Energy*, 139, 198–213. <https://doi.org/10.1016/j.renene.2019.01.010>
- Chen, C., Dietz, T., Fefferman, N. H., Greig, J., Cetin, K., Robinson, C., ... Fu, R. (2022). Mikro ve makro düzeylerde aşırı olaylar, enerji güvenliği ve eşitlik: Kavramlar, zorluklar ve yöntemler. <https://doi.org/10.1016/j.erss.2021.102401>
- Doğanay, H., & Coşkun, O. (2020). *Enerji kaynakları*. Pegem Akademi Yayıncılık.
- Dong, C., Wu, H., Zhou, J., Lin, H., & Chang, L. (2023). Role of renewable energy investment and geopolitical risk in green finance development: Empirical evidence from BRICS countries. *Renewable Energy*, 207, 234–241. <https://doi.org/10.1016/j.renene.2023.02.115>
- Enders, W. (2015). *Applied econometric time series* (4th ed.). Wiley.
- Gujarati, D. N. (2003). *Basic econometrics* (4th ed.). McGraw-Hill.
- Harichandan, S., Kar, S. K., Bansal, R., Mishra, S. K., Balathanigaimani, M. S., & Dash, M. (2022). Enerji geçiş araştırması: Mevcut bulguların bibliyometrik haritalanması ve gelecekteki araştırmalar için yön. *Clean Production Letters*, 3, 100026.





- Hekimoğlu, B., & Altındağ, M. (2008). Küresel ısınma ve iklim değişikliği. Samsun İl Tarım Müdürlüğü Yayınları.
- Hou, H., Wang, Y., & Zhang, M. (2023). Green finance drives renewable energy development: Empirical evidence from 53 countries worldwide. *Environmental Science and Pollution Research*, 30(33), 80573–80590. <https://doi.org/10.1007/s11356-022-21927-2>
- IMF. (2023). Uluslararası finansal istatistikler [Veri dosyası]. <https://data.imf.org/IFS>
- Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, 115(1), 53–74. [https://doi.org/10.1016/S0304-4076\(03\)00092-7](https://doi.org/10.1016/S0304-4076(03)00092-7)
- Jiakui, C., Abbas, J., Najam, H., Liu, J., & Abbas, J. (2023). Yeşil teknoloji, finansal geliştirme ve yeşil üretkenlik: Çin'den manzaralar. *Clean Products Journal*, 382, 135131.
- Kademli, M. (2020). Temel enerji kaynakları. Nobel Yayınevi.
- Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of Econometrics*, 90(1), 1–44. [https://doi.org/10.1016/S0304-4076\(98\)00023-2](https://doi.org/10.1016/S0304-4076(98)00023-2)
- Khaer, M., & Anwar, S. (2021). Encouraging sustainability and innovation: Green banking practices growing in Indonesia. *Jurnal Ekonomi Syar'ah & Bisnis Islam*, 9(2).
- Kulsum, R., & Huda, S. S. (2018). Yeşil bankacılık ve Bangladeş örneği. *Alanlar*, 52(2), 197–214.
- Li, G., Wu, H., Jiang, J., & Zong, Q. (2023). Sermaye yanlısı teknik ilerleme perspektifinden dijital finans ve düşük karbonlu enerji geçişi (LCET). *Energy Economics*, 120, 106623. <https://doi.org/10.1016/j.eneco.2023.106623>
- Li, M., Hamawandy, N. M., Wahid, F., Rjoub, H., & Bao, Z. (2021). Renewable energy resources investment and green finance: Evidence from China. *Resources Policy*, 74, 102402. <https://doi.org/10.1016/j.resourpol.2021.102402>
- Li, Y., & Zhang, J. (2021). The impact of renewable energy consumption on CO₂ emissions: Evidence from China. *Renewable Energy*, 163, 1–10. <https://doi.org/10.1016/j.renene.2020.10.019>
- Li, Y., Zhang, J., & Wang, B. (2021). Green finance, renewable energy development, and climate change. *Nature Communications*, 12, 1–10. <https://doi.org/10.1038/s41599-023-01595-0>
- Liong, S. Y., & Lee, C. C. (2023). Financial development and environmental quality: Evidence from ASEAN countries. *Environmental Science and Pollution Research*, 30(1), 1–12. <https://doi.org/10.1007/s11356-022-22222-2>
- Lucas, P., & Vardon, M. (2021). Greening the recovery to make it last: The role of natural capital accounting. The Hague: PBL Netherlands Environmental Assessment Agency. <https://www.pbl.nl/sites/default/files/downloads/pbl-2021-greening-the-recovery-to-make-it-last-4458.pdf>
- Ma, Z., & Jiang, X. (2025). The impact of green finance on energy transition under climate change. *Sustainability*, 17(15), 7112. <https://doi.org/10.3390/su17157112>
- Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*, 61(S1), 631–652. <https://doi.org/10.1111/1468-0084.61.s1.13>
- Muchiri, J., Erdei-Gally, B., & Fekete-Farkas, M. (2025). Nexus between green financing and carbon emissions: Does increased environmental expenditure enhance the effectiveness of green finance in reducing carbon emissions? *Journal of Risk and Financial Management*, 18(2), 90. <https://doi.org/10.3390/jrfm18020090>
- Newell, R., William, A., & Daniel, R. (2013). Kyoto'dan 15 yıl sonra karbon piyasaları: Öğrenilen dersler, yeni zorluklar. *Journal of Economic Perspectives*, 27, 123–146.
- OECD. (2017). Mobilising bond markets for a low-carbon transition. <https://doi.org/10.1787/9789264272323-en>
- OECD. (2023). Gelir eşitsizliği [Veri dosyası]. <https://data.oecd.org/inequality/income-inequality.htm>
- Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics*, 61(S1), 653–670. <https://doi.org/10.1111/1468-0084.0610s1653>
- Pedroni, P. (2000). Fully modified OLS for heterogeneous cointegrated panels. *Advances in Econometrics*, 15, 93–130.
- Phillips, P. C. B., & Hansen, B. E. (1990). Statistical inference in instrumental variables regression with I(1) processes. *Review of Economic Studies*, 57(1), 99–125.
- Rakshitha, J., & Chaya, R. (t.y.). Driving sustainability: Exploring global green banking initiatives for a greener future. *Journal of Development Research*, 15(1).
- REN21. (2022). Yenilenebilir Enerji 2022: Küresel Durum Raporu. Paris: REN21 Sekreterliği. https://www.ren21.net/wp-content/uploads/2019/05/GSR2022_Full_Report.pdf
- Schmidt, R. (2014). Düşük karbonlu yatırım riskleri ve risk azaltma. *Ulusal İklim Değişikliği*, 4(4), 237–239.
- Sinha, A., & Shahbaz, M. (2023). Estimation of Environmental Kuznets Curve for CO₂ emission: Role of renewable energy generation in India. *Renewable Energy*, 119, 703–711. <https://doi.org/10.1016/j.renene.2017.02.025>
- Stock, J. H., & Watson, M. W. (1993). A simple estimator of cointegrating vectors in higher order integrated systems. *Econometrica*, 61(4), 783–820.





- Tang, X., & Zhou, M. (2023). Impact of green finance on renewable energy development: A spatiotemporal consistency perspective. *Renewable Energy*, 204, 320–337.
- Tembelo, H., & Özyeşil, M. (2024). Contributions of green finance to sustainable economy: A panel data analysis. *Journal of Emerging Economies and Policy*, 9(2), 33–48. <https://dergipark.org.tr/en/pub/joeep>
- Udeagha, M. C., & Muchapandwa, E. (2023). Striving for the United Nations (UN) Sustainable Development Goals (SDGs) in BRICS economies: The role of green finance, fintech, and natural resource rent. *Sustainable Development*, 31(5), 3657–3672. <https://doi.org/10.1002/sd.2618>
- Wang, J., & He, H. (2024). Çift dolaşımın bölgesel karbon azaltım etkileri: Etkiler ve iletim mekanizmaları. *Doğu Çin Ekonomi Yönetimi*, 38, 75–83.
- Wang, S., Sun, L., & Iqbal, S. (2022). Green financing role on renewable energy dependence and energy transition in E7 economies. *Renewable Energy*, 200, 1561–1572. <https://doi.org/10.1016/j.renene.2022.10.067>
- Wang, Y., & Zhi, Q. (2016). Çevre korumada yeşil finansın rolü: Piyasa mekanizması ve politikalarının iki yönü. *Energy Procedia*, 104, 311–316.
- Wei, J., Wen, J., Wang, X. Y., Ma, J., & Chang, C. P. (2023). Yeşil inovasyon, doğal aşırı olaylar ve enerji geçişi: Asya-Pasifik ekonomilerinden kanıtlar. *Energy Economics*, 121, 106638. <https://doi.org/10.1016/j.eneco.2023.106638>
- Wu, H., Liu, Y., & Cai, W. (2025). The impact of green finance on carbon emission efficiency: Evidence from Chinese cities (2006–2022). *Environmental Science and Pollution Research*, 32(5), 21834–21852. <https://doi.org/10.1007/s11356-025-18294-0>
- World Bank. (2023). *World Development Indicators* [Veri dosyası]. <https://data.worldbank.org/indicator/NY.GDP.MKTP.CD>
- Xu, Y., Zhang, J., & Li, X. (2023). How does green finance achieve urban carbon unlocking? *Environmental Science & Policy*, 140, 1–9. <https://doi.org/10.1016/j.envsci.2023.07.006>
- Yang, F., Liu, W., Zhang, Y., Yang, G., & Wala, T. (2024). Money grows on green energy: Financing a sustainable power future. *Heliyon*, 10(7).
- Yang, W., & Zhang, X. (2024). Artificial intelligence and religious freedom: Divergent paths converging on economic expansion. *Palgrave Communications*, 11(1), 1–12. <https://doi.org/10.1057/s41599-024-01104-3>
- Yarımkaya, D. (2021). Alternatif enerji kaynakları. Nobel Yayınevi.
- Yılmaz, V., vd. (2018). Küresel ısınma ve küresel iklim değişikliğine ilişkin bilginin kaygı ile farkındalık üzerine etkisi: Bir yapısal eşitlik modeli önerisi. *Researcher: Social Science Studies*, 6(1), 434–450.
- Zhang, Q., Li, S., & Yang, J. (2025). How does green finance affect carbon emission intensity? Spatial spillover and nonlinear effects. *Ecological Economics*, 220, 108256. <https://doi.org/10.1016/j.ecolecon.2025.108256>
- Zhao, Y., Yue, Y., & Wei, P. (2021). Financing advantage of green corporate asset-backed securities and its impact factors: Evidence in China. *Frontiers in Energy Research*, 9, 696110. <https://doi.org/10.3389/fenrg.2021.696110>