https://doi.org/10.7251/EMC2603749K UDK: 004.738.5:351.824.11(4/9)

Datum prijema rada: 3. mart 2026.
Submission Date: March 3, 2026
Datum prihvatanja rada: 27. avgust 2026.
Acceptance Date: August 27, 2026

Časopis za ekonomiju i tržišne komunikacije
Economy and Market Communication Review

Godina/Vol. **XVI** • Br./No. **III**
str./pp. 749-770

ORIGINALNI NAUČNI RAD / ORIGINAL SCIENTIFIC PAPER

THE IMPACT OF BANKING SECTOR DEVELOPMENT ON SUSTAINABLE ENVIRONMENTAL QUALITY: APPLICATION OF OECD COUNTRIES

A. Selcuk Koyluoglu | Assoc. Prof., Selcuk University, Kulu Vocational School, Department of Foreign Trade, Kulu, Konya, Turkiye, askoyluoglu@selcuk.edu.tr; ORCID ID: 0000-0003-0359-1443

Murat Tekbas | Assoc. Prof., Afyon Kocatepe University, Afyon Vocational School, Department of Management and Organization, Afyon, Turkiye, mtekbas@aku.edu.tr; ORCID ID: 0000-0003-2589-2482

H. Serhat Cerci | Assist. Prof., Selcuk University, Silifke Tasucu Vocational School, Department of Travel, Tourism and Entertainment Services, Silifke, Mersin, Turkiye, serhatcerci@selcuk.edu.tr; ORCID ID: 0000-0002-5580-2057

Mesut Dogan | Prof. Dr., Bilecik S.E. University, Bozuyuk Vocational School, Department of Banking and Insurance, Bozuyuk, Bilecik, Turkiye, mesut.dogan@bilecik.edu.tr; ORCID ID: 0000-0001-6879-1361

Abstract: *This study examines the impact of banking sector development, economic growth, energy consumption, and renewable energy consumption on environmental quality (CO2 emissions) and sustainability-oriented policy design in 26 OECD countries over the period 2001-2021. Utilizing robust econometric techniques for panel data, including LLC/IPS unit root tests, Pedroni/Kao cointegration, FMOLS/DOLS estimations, and Dumitrescu-Hurlin (2012) causality tests, this study aims to clarify the environmental role of the financial system. The empirical findings demonstrate that banking sector development and renewable energy consumption significantly reduce CO2 emissions, while economic growth leads to an increase in emissions. Furthermore, the causality analysis reveals a bidirectional relationship between banking sector development, renewable energy, and CO2 emissions. The study's 20-year scope and robust methodology enhance its credibility. Its main contribution lies in revealing the environmental benefits of financial development—an underexplored topic offering valuable insights for green growth and sustainability-oriented policy design. These findings suggest that policymakers should promote green credit allocation and integrate ESG frameworks into banking regulations to accelerate the transition to sustainable energy.*

Keywords: *Banking Sector, CO2, Sustainable Environment, OECD Countries*

JEL Classification: *A100, F18, G21, Q56, Q58*

Table 1. List of abbreviations

BoC	Bank of Canada	**ESG**	Environmental, Social, and Governance
BoJ	Bank of Japan	**FMOLS**	Fully Modified Ordinary Least Square
CO2	carbon dioxide	**GND**	Green New Deal
DOLS	Dynamic Ordinary Least Squares	**GSS**	Green, Social and Sustainability
EBA	European Banking Authority	**IEA**	International Energy Agency
ECB	European Central Bank	**OECD**	The Organization for Economic Cooperation and Development
EGD	European Green Deal	**SLB**	Sustainability Linked Bond

Source: authors

INTRODUCTION

The OECD is an international organization comprised of countries with high economic development and democratic principles. It consists of 38 member states, including the EU, the US, Canada, Japan, South Korea, Sweden, and Turkey (OECD, 2025). These countries, possessing vast energy resources, play a dominant role in global energy dynamics, with the power to regulate global market stability and influence energy security (Umar and Safi, 2023). However, this critical role also necessitates the diversification of economies and the fight against environmental challenges such as climate change. Financial development plays a significant role in this pursuit of sustainability (OECD, 2020; Shahbaz et al., 2023; Ganda, 2019).

Although green environmental policies have become a rising trend in the last decade, global carbon emissions continue to increase (Shahbaz et al., 2018; Haug and Ucal, 2019). In OECD countries, the average per capita CO_2 emissions for 2023 are reported to be approximately 6.43 metric tons (Umar and Safi, 2023; Ganda, 2019). IEA reports also confirm that this upward trend continues (IEA, 2025). Environmental economists attribute this negative trend to policy failures and the exploitation of resources by industrial sectors while disregarding green sustainability (Ren et al., 2022). Environmental degradation is more pronounced in developing economies due to low technological advancement and lack of legislation (Adams and Klobodu, 2018). In this process, the banking sector, one of the most important actors in the financial system, can promote environmental sustainability by directing capital flows (Ahad et al., 2019). Environmentally sensitive green financing practices contribute to protecting environmental quality, while policies that do not take these dynamics into account can finance activities that harm the environment. Therefore, systematically examining the relationship between banking development and environmental quality is critical for aligning the financial system with the Sustainable Development Goals (Acheampong, 2019; Yang et al., 2021).

Operating with this perspective, OECD countries are using the banking sector as a tool to develop environmental policies (Samour et al., 2022; Umar and Safi, 2023). Many strategic practices have been implemented in member states to this end. For instance, under the European Green Deal, climate risks have become a key criterion in credit allocation. The EBA has developed sustainability standards, and the German KfW Bank offers low-interest loans to low-carbon projects (KfW Bank, 2025). In France and Canada, the Banque de France is conducting stress tests for climate risks (OECD, 2018), while the Bank of Canada is conducting a "Climate Scenario Analysis" to measure financial stability (BoC, 2025). Similarly, in the US and Japan, JPMorgan Chase has committed $2.5 trillion in financing for climate initiatives, and the Bank of Japan (BoJ) has launched a low-interest loan program for green investments (World Bank, 2016, 2018; BoJ, 2025). Furthermore, South Korea restructured its banking sector with the "Korean Green New Deal" (Korea's GND, 2020), while the Swedish Central Bank removed carbon-intensive sector bonds from its reserves (WCED, 1987; Riksbank, 2020). The OECD's "Green Finance and Investment Centre" also promotes information sharing and the development of environmentally friendly financial products among member countries (OECD, 2020). For clarity, these practices across the OECD are visualized in Table 2.

Table 2. Banking sector practices towards sustainable environmental quality in OECD countries

Country	Policy	Parameter
EU (OECD Countries)	ECB climate stress tests EBA ESG disclosure standards KfW, Banque de France green loans	Global GSS+ (Green, Social and Sustainability) · SLB (Sustainability Linked Bond) bond volume: ~$4.2 trillion Q3 2023 2023 green bonds: $575 billion
USA and Canada	JPMorgan: $2.5 trillion financing under "net zero" target BoC climate scenarios and stress tests	Total US and Canadian SLB/Bond issuance on the rise in 2023; global GSS+ bonds account for 5% (~$618 billion)

Japan	BOJ green loan programs (since 2021)	Japan leads in sustainable bond issuance in 2023 (based on country)
South Korea	Green New Deal Low cost green financing through government bank partnerships	US, France, China, and South Korea ranked among the top 15 in GSS+ issuance
Sweden	Riksbank removes carbon intensive bonds from portfolio (2020)	–
OECD General	OECD General Green Finance & Investment Centre Green Recovery Database Reports on the green/growth potential of bond markets	Green bond issuance in developing countries increased by 34% in 2023 ($135 billion) OECD forecast: The market could reach $4.7–5.6 trillion in 2035

Source: oecd.org; unepfi.org; finance.ec.europa.eu/sustainable; equator principles.com; ngfs.net; fsb tcfd.org; www.worldbank.org; climatebonds.net; bis.org

This study examines the impact of the banking sector on environmental sustainability (CO2) using data from 26 OECD countries for the period 2001–2021 (OECD, 2020). Stationarity of the series was investigated using LLC and PP tests, long-term relationships using Pedroni and Kao cointegration tests; coefficients were estimated using FMOLS and DOLS methods. Causality between variables was analyzed using the Dumitrescu–Hurlin test. According to the FMOLS and DOLS results, the development of the banking sector and renewable energy consumption significantly reduce CO2 emissions, while economic growth leads to an increase in emissions. Causality analysis reveals a bidirectional relationship between banking sector development, renewable energy, and CO2 emissions. In conclusion, the study empirically demonstrates that a mature banking structure is a critical driving force in carbon reduction in OECD countries.

LITERATURE BACKGROUND

The Impact of the Banking Sector on Environmental Quality and Sustainable Financial Development

In academic literature, the role of the banking sector on environmental quality is a complex area explained by two fundamental opposing mechanisms. First, the "scale effect" argues that financial development stimulates economic activity, increasing energy consumption and exacerbating environmental degradation. Sadorsky (2010) supported this view by confirming, in a panel data analysis of 22 developing countries, that financial development, as measured by banking and equity indicators, significantly increased energy consumption. Similarly, a quantile regression analysis by Rădulescu et al. (2022) revealed that a 1% expansion in the banking sector in OECD countries increased the ecological footprint due to the flow of resources to carbon-intensive sectors. Second, the "technical and structural effect" argues that the financial system improves environmental quality by directing capital to efficient projects, financing technological innovations, and promoting green investments.

Proponents of this view include Tamazian et al. (2009), who empirically demonstrated in their study of BRIC countries that a well-functioning banking sector reduces CO2 emissions by facilitating technology transfer and financing energy-efficient projects. This study aims to determine whether economies of scale or technical effects are more dominant in the context of OECD countries. Current literature emphasizes the critical role of the banking sector in structuring sustainable development and environmental quality in OECD countries, where economic development and regulatory policies converge to shape green activities (Halkos and Polemis, 2017; Li and Ayub, 2025).

The Relationship Between Banking Sector Development and Sustainable Environmental Quality in OECD Countries

Effective banking practices can both accelerate and hinder environmental progress depending on their strategic orientations. Consequently, banking institutions in OECD countries are increasingly recognized as critical structures capable of mobilizing resources for sustainable infrastructure, driven by a complex interplay of risk management and technological innovation (Halkos and Polemis, 2017; Wang et al., 2023; Li and Ayub, 2025).

The expansion of the banking sector affects environmental outcomes by creating resources for both traditional and green investments. For example, using quantile regression, Rădulescu et al. (2022) provide empirical evidence that 1% growth in the banking sector is associated with an increase in ecological footprint in OECD countries. This finding shows that misguided banking sector development can worsen environmental degradation. On the other hand, a strong banking system can direct funds to renewable energy projects and clean technology investments. Beka and Abazi-Alili (2024) showed that the increase in banking performance, measured by financial stability and return on assets, in OECD countries is positively correlated with renewable energy consumption. Furthermore, as discussed by Aras and Kazak (2022) and Shabir et al. (2024), banks integrating environmental, social, and governance (ESG) practices into their lending decisions are more likely to support sustainable projects. Including ESG criteria in lending processes mitigates the negative effects of uncontrolled credit expansion. Banks' interest in ESG criteria stems from a sense of corporate social responsibility, as well as the need to manage physical risks related to climate change and transition risks to the devaluation of fossil fuel assets (Bolton et al., 2020).

The effects of the banking sector are also evident in the real economy. In OECD countries, there is a long-term interdependence between the banking sector and the real sector, and financed activities can cause positive or negative environmental externalities (Sendeniz-Yuncu et al., 2008). Increased credit flows to carbon-intensive industries lead to high emissions (Rădulescu et al., 2022), while a transition to sustainable development may be possible when banks prioritize green technology and are supported by effective ESG frameworks (Aras and Kazak, 2022; Shabir et al., 2024). The effects of the banking sector cannot be considered independently from the economic growth dynamics explained by the Environmental Kuznets Curve (EKC) hypothesis. Formulated by Grossman and Krueger (1995), this hypothesis suggests that growth initially increases environmental degradation, but after a certain income level, structural change and environmental awareness lead to improvements in environmental quality. However, the validity of the EKC hypothesis is debatable; many studies, even in OECD countries, have shown that a monotonically increasing relationship has been found between economic growth and emissions (Apergis and Payne, 2010; Apergis and Ozturk, 2015; Acheampong, 2019).

At this point, financial development can "flatten" the EKC curve by financing technological innovations and initiating environmental improvements at lower income levels (Tamazian et al., 2009; Zhang, 2011). Shahbaz et al. (2013) showed that in the case of Malaysia, financial development can alter the EKC model with investments that increase energy efficiency. Dang and Dang (2019) emphasize that improving environmental quality requires coordinated policy measures that target resource efficiency while reducing pollution. This shows that the impact of banking sector development depends on institutional frameworks. Therefore, policymakers in OECD countries should consider regulatory reforms aimed at aligning banking practices with goals such as tax incentives that encourage green loans.

At the heart of environmental quality discussion lies the structure of energy consumption. Dogan and Seker (2016), in their panel analysis of EU countries, showed that a 1% increase in non-renewable energy consumption increased CO2 emissions by 0.32%, while a 1% increase in renewable energy consumption reduced emissions by 0.16%. Renewable energy projects are dependent on external financing due to high initial investment costs. Empirical studies by Ren et al. (2022) and Mehmood (2023) demonstrate that banking sector development directly encourages investment in renewable energy projects by providing low-cost, long-term loans and facilitates the achievement of emission reduction targets.

The literature shows that the banking sector plays a key role in achieving the Sustainable Development Goals in OECD countries, and that this effect depends on credit quality. Creating regulatory frameworks that encourage green investments in banking (e.g., climate stress tests) can be a significant catalyst in reducing the environmental costs of growth and accelerating the transition to renewable energy. Therefore, the relationship between banking development and environmental quality, along with economic growth, total energy consumption, and renewable energy dynamics, should be evaluated within a multidimensional framework. This study aims to fill precisely this gap.

METHODOLOGY

Data and Research Model

This section examines the relationship between banking sector development, economic growth, energy use, renewable energy consumption, and CO2 emissions across 26 OECD member countries over the period 2001–2021. To form a balanced panel dataset and empirically analyze the impacts of financial development and economic growth on carbon emissions, the baseline econometric model is formulated in logarithmic form, following the frameworks of Samour et al. (2022) and Mehmood (2023). The mathematical formulation of the baseline model is presented in Equation (1), and its conceptual framework is illustrated in Figure 1.

$$lnCO2_{it} = \beta_0 + \beta_1 lnBANK_{it} + \beta_2 lnGDPPC_{it} + \beta_3 \, lnENU_{it} + \beta_4 lnRENE_{it} + \vartheta_t \quad (1)$$

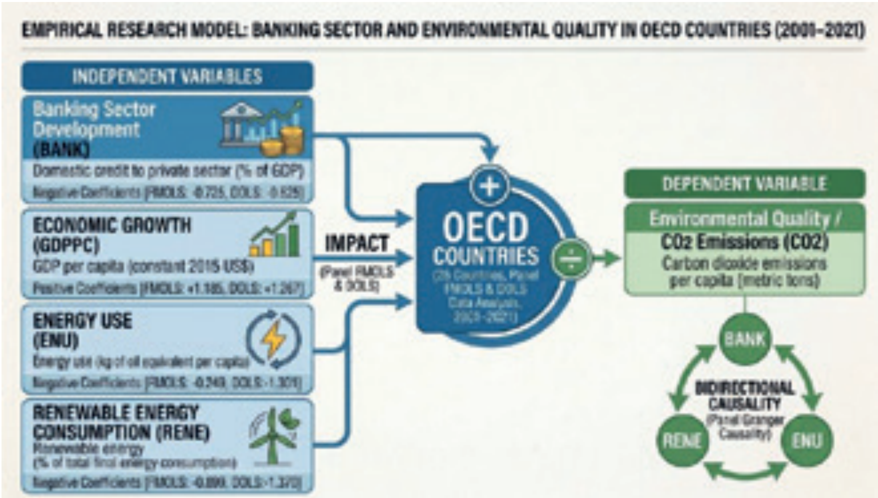

Figure 1. Research Model

Source: authors

The natural logarithm of all variables in the model has been taken. *lnCO2,* representing environmental quality, is carbon dioxide emissions per capita; *lnBANK,* representing banking sector development, is the domestic credit to the private sector by banks; *lnGDPPC,* representing economic growth, is *GDP* per capita. As control variables, *lnENU* represents total energy use, *lnRENE* represents renewable energy consumption, and ϑ_t represents the error term. Detailed information about the variables is presented in Table 3.

Table 3. Variable definitions

Variables	Symbol	Definition	Unit	Source
CO2 emissions	CO2	Carbon dioxide emissions (total) excluding LULUCF	Metrics tons per capita	World Develop ment Indicators
Banking Sector Development	BANK	Domestic credit to private sector by banks	% of GDP	World Develop ment Indicators
GDP Per Capita	GDPPC	GDP per capita	constant 2015 US$	World Develop ment Indicators
Energy Use	ENU	Energy Use	Kg of oil equiva lent per capita	World Develop ment Indicators

Renewable Energy	RENC	Renewable Energy Consumption	% of total final energy consumption	World Development Indicators

Source: authors

Methodologically, the study first examines the stationarity of the variables using the Levin et al. (2002) and Im et al. (2003) panel unit root tests. Following the stationarity analysis, the cointegration relationship among the series is tested using the Pedroni and Kao cointegration methods. Furthermore, the cointegration coefficients and their direction are analyzed using the FMOLS (Fully Modified Ordinary Least Squares) method developed by Pedroni (2000) and the DOLS (Dynamic Ordinary Least Squares) method developed by Stock and Watson (1993). Finally, the causal relationship between the variables is investigated with the Dumitrescu-Hurlin (2012) panel causality test.

Initially, the Levin et al. (2002) and Im et al. (2003) panel unit root tests are used to determine the stationarity of the series. The *LLC* test is one of the significant tests that examines the common unit root process in panel data sets. The assumption of a common autoregressive coefficient *(β)* for all cross-sectional units increases the power of the test, but it can be restrictive due to its homogeneity assumption. It has been reported that the test can be applied in models with a constant, a constant and trend, or with a constant and lagged differences (Baltagi, 2005). The equation for the *LLC* panel unit root test is expressed as follows:

$$\Delta y_{it} = \delta y_{it-1} + \sum_{L=1}^{p_i} \theta_{iL} \Delta y_{it-L} + \propto_{mi} d_{mt} + \varepsilon_{it}, \qquad m = 1,2.3 \qquad (2)$$

The H0 hypothesis of the *LLC* test is "there is a unit root in the panel," while the alternative hypothesis H1 is "there is no unit root in the panel." The IPS test, the second unit root test applied to the model, allows for different autoregressive coefficients in individual cross-sections. In this test, where the *ADF* test is applied separately for each cross-section, the test statistic is generated by taking the average of these results. The equation for the *IPS* panel unit root test is as follows:

$$\Delta y_{i,t} = \alpha_i + p_i y_{i,t-1} + \delta_{i,t} \qquad (3)$$

The H0 hypothesis of the more flexible *IPS* panel unit root test is "all series have a unit root," whereas the H1 hypothesis posits the assumption that "some series are stationary." The Pedroni cointegration test, applied to perform cointegration analysis in panel data, presents seven different test statistics (Pedroni, 2004). These tests include both group and panel statistics. Allowing for heterogeneous cointegration vectors is considered a strength of the method. The formulas for the test are presented in Table 4. The Kao cointegration test is a test with the same approach as the Pedroni test (Pedroni, 1999). Proposing *DF* and *ADF*-type tests to examine the cointegration relationship, the Kao test is frequently used due to its simple structure.

Table 4. Pedroni cointegration test statistics

(Within-dimension)			
First Section	1	Panel v-statistics	$T^2 N^{3/2} Zv_{N,T} \equiv T^2 N^{3/2} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} L_{11i}^{-2} e_{i,t-1}^{2}\right)^{-1}$
	2	Panel p- statistics	$T\sqrt{N}\, Z_{p_{N,T^{-1}}} \equiv T\sqrt{N}\left(\sum_{i=1}^{N} \sum_{t=1}^{T} L_{11i}^{-2} e_{i,t-1}^{2}\right)^{-1}$
	3	Panel t- statistics	$Z_{tN,T} \equiv \left(\sigma_{N,T}^{*2} \sum_{i=1}^{N} \sum_{t=1}^{T} L_{11i}^{-2} e_{i,t-1}^{2}\right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} L_{11i}^{-2} \left(e_{i,t-1}^{*} \Delta e_{it} - \lambda_i\right)$
		(non-Parametric)	
	4	Panel t- statistics Parametric	$Z_{tN,T}^{*} \equiv \left(S_{N,T}^{*2} \sum_{i=1}^{N} \sum_{t=1}^{T} L_{11i}^{-2} e_{i,t-1}^{2}\right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} L_{11i}^{-2} e_{i,t-1}^{*} \Delta e_{it}^{*}$
(Between-dimension)			
Second Section	5	Grup-p statistics	$TN^{-1/2} Z_{p_{N,T^{-1}}} \equiv TN^{-1/2} \sum_{i=1}^{N}\left(\sum_{t=1}^{T} e_{i,t-1}^{2}\right)^{-1} \sum_{t=1}^{T}\left(e_{i,t-1} \Delta e_{it} - \lambda_i\right)$
	6	Grup-t statistics (non -parametric)	$N^{-1/2} Z_{p_{N,T^{-1}}} \equiv N^{-1/2} \sum_{i=1}^{N}\left(\sigma_i^2 \sum_{t=1}^{T} e_{i,t-1}^{2}\right)^{-1/2} \sum_{t=1}^{T}\left(e_{i,t-1} \Delta e_{it} - \lambda_i\right)$
	7	Grup-t statistics (Parametric)	$N^{-1/2} Z_{p_{N,T^{-1}}} \equiv N^{-1/2} \sum_{i=1}^{N}\left(\sum_{t=1}^{T} s_i^{*2} e_{i,t-1}^{2*}\right)^{-1/2} \sum_{t=1}^{T} e_{i,t-1}^{*} \Delta e_{it}^{*}$

Source: authors

To analyze the cointegration coefficients of the dependent and independent variables in the model, the *FMOLS* (Fully Modified Ordinary Least Squares) method developed by Pedroni (2000) is used. This method offers the ability to estimate coefficients accurately and without bias when a cointegration relationship exists in panel data. Its strengths are particularly noted in its ability to correct for serial correlation and endogeneity problems between the error terms and explanatory variables. The panel regression model on which the *FMOLS* method is based is as follows:

$$y_{it} = \alpha_i + \beta x_{it} + \mu_{it} \quad X_{it} = X_{it-1} + e_{it} \qquad (4)$$

In the equations, *y_it* represents the dependent variable, *x_it* the independent variable, *α_i* the constant term, and *μ_it* the error term. In this model, both *x_it* and *y_it* are *I(1)* processes and are cointegrated. Pedroni (2001) applied the *FMOLS* method to panel data. The extended equation for the panel is as follows:

$$\hat{\beta}^{*}_{GFM} = N^{-1} \sum_{i=1}^{N} \beta^{*}_{FM,i} \qquad (5)$$

In Equation 5, *β_(FM,i)^** represents the cointegration coefficients obtained from the *FMOLS* estimation for each cross-section. Additionally, the t-statistics for the group-mean panel *FMOLS* method are derived from the statistics of the cointegration coefficient obtained from the *FMOLS* estimation for each individual cross-section. The calculation of these t-statistics is performed as follows:

$$t_{\hat{\beta}^{*}_{GFM}} = N^{-1/2} \sum_{i=1}^{N} t_{\hat{\beta}^{*}_{FM,i}} \qquad (6)$$

In the equation, *t_(β ̂_(FM,i)^*)* represents the t-statistic for the cointegration coefficient obtained for each cross-section included in the panel (Nazlıoglu, 2010).

The Dumitrescu-Hurlin (2012) Panel Granger causality test, frequently used to investigate causality in panel data studies, calculates average statistics by performing individual Granger tests for each unit. The advantages of this method include its applicability in cases where the time dimension is larger than the cross-sectional dimension (T > N) as well as when the cross-sectional dimension is larger than the time dimension (N > T). The model, which analyzes the causality relationship between stationary series, is as follows (Dumitrescu and Hurlin, 2012):

$$y_{it} = \alpha_i + \sum_{k=1}^{p} \gamma_i^{(k)} y_{it-k} + \sum_{k=1}^{p} \beta_i^{(k)} x_{it-k} + \epsilon_{it} \quad (7)$$

The H0 hypothesis of the test is "there is no Granger causality from x to y," while the alternative hypothesis H1 is "there is Granger causality from x to y." In this model, which has a heterogeneous structure, the null hypothesis assumes homogeneity of the results, whereas the alternative hypothesis allows for heterogeneity. It is also noted that the stationarity of the series is important for the application of the test (Celik and Unsur, 2020).

RESULTS

This section of the study presents the results from the analysis methods applied to the model constructed to explain the relationship between CO2 emissions, banking sector development, economic growth, energy use, and renewable energy consumption in OECD member countries. Before presenting the findings, descriptive statistics for the dependent and independent variables that constitute the model are presented in Table 5. Upon examining the descriptive statistics in Table 5, it is seen that the maximum logarithmic value of 8.680 for the *lnCO2* emissions variable occurred in the USA in 2004 with 5,888.17 *MT CO2e.* The minimum logarithmic value of 1.084 was observed in Iceland in 2001 with 2.959 *MT CO2e.* For the *lnBANK* variable, which indicates banking sector development, the highest logarithmic value of 5.718 was in Iceland in 2006 with 304.575 *(% of GDP*), while the minimum value of 2.401 was recorded in Mexico in 2001 with 11.087 *(% of GDP).* For the *lnGDPPC* variable, the maximum logarithmic value of 11.453 was in Ireland in 2021 with $94,184, and the minimum logarithmic value of 8.299 was in Colombia in 2001 with $4,020. The maximum logarithmic value of 9.809 for the *lnENU* variable was observed in Iceland in 2013 with 18,212 kg of oil equivalent per capita.

Table 5. Descriptive statistics for the variables

Variables	lnCO2	lnBANK	lnGDPPC	lnENU	lnRENE
Mean	4.864	4.349	10.211	8.086	2.624
Median	4.603	4.494	10.463	8.175	2.653
Maximum	8.680	5.718	11.453	9.809	4.417
Minimum	1.084	2.401	8.299	6.448	0.356
Std.Dev.	1.545	0.573	0.693	0.631	0.988
Skewness	0.044	0.901	0.726	0.191	0.520
Kurtosis	3.387	3.698	2.538	3.673	3.044
Observations	546	546	546	546	546

Source: authors

In panel data analyses, stationarity of the series is necessary to obtain reliable results. Accordingly, the stationarity of the series must be tested to establish a significant relationship and achieve accurate results. The results of the Levin et al.,

(2002) and Im et al., (2003) panel unit root tests, which are frequently used methods in panel data analysis, are shown in Table 6.

Table 6. Panel unit root test results

Level	LLC		IPS	
	With constant and trend			
	t- statistic	Prob.	t- statistic	Prob.
lnCO2	1.648**	0.049	1.145	0.126
lnBANK	2.227**	0.013	0.288	0.386
lnGDPPC	2.120**	0.017	3.112***	0.009
lnENU	5.5811***	0.000	5.012***	0.000
lnRENE	1.865**	0.031	0.048	0.519
First Difference				
ΔlnCO2	5.439***	0.000	8.840***	0.000
ΔlnBANK	13.348***	0.000	9.643***	0.000
ΔlnGDPPC	13.781***	0.000	12.026***	0.000
ΔlnENU	16.034***	0.000	16.065***	0.000
ΔRENE	18.066***	0.000	16.113***	0.000

Note: Δ indicates the first difference of the series. *** and ** denote significance at the 1% and 5% levels, respectively

Source: authors

When the results of the unit root tests are examined, it is observed that in both test results, the *lnGDPPC* and *lnENU* variables are stationary at the level, while the other variables have a unit root at the level. However, after applying the first difference, it is determined that all variables become stationary according to both the *LLC* and *IPS* unit root test results.

Table 7. Panel cointegration test results

Pedroni Panel Cointegration Test	With Constant (No Trend)		Weighted	
	t- statistic	Prob.	t-statistic	Prob.
Panel v statistic	1.078	0.140	0.248	0.598
Panel rho statistic	0.975	0.835	0.782	0.782
Panel PP statistic	3.547***	0.000	5.336***	0.000
Panel ADF statistic	4.121***	0.000	4.913***	0.000

Group rho statistic	2.757	0.997
Group PP statistic	7.461***	0.000
Group ADF statistic	5.202***	0.000
Kao Panel Cointegration Test	**t- statistic**	**Prob.**
ADF	2.522***	0.005

Note: *** denotes significance at the 1% level

Source: authors

After determining the stationarity of the series, the cointegration relationship among them was examined using the Pedroni and Kao cointegration tests. In the results of the Pedroni cointegration test shown in Table 7, the null hypothesis is rejected at the 1% significance level in two of the four panel tests, indicating the existence of a cointegration relationship. The Group *PP* and Group *ADF* statistics from the Pedroni method's Group tests are also statistically significant at the 1% level. The results of the Kao cointegration test, the second cointegration test applied to verify the analysis, also confirm the presence of a cointegration relationship.

The coefficient and direction of the cointegration relationship obtained from the Pedroni and Kao tests were analyzed using *FMOLS* and *DOLS* estimators, and the results are presented in Table 8.

Table 8. Coefficient estimation test results

Model	$lnCO2_{it} = \beta_0 + \beta_1 lnBANK_{it} + \beta_2 lnGDPPC_{it} + \beta_3\ lnENU_{it} + \beta_4 lnRENE_{it} + \vartheta_t$							
FMOLS								
Variable	**lnBANK**		**lnGDPPC**		**lnENU**		**lnRENE**	
Panel	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**
	-0.725***	0.000	1.185***	0.000	-0.249***	0.000	-0.899***	0.000
DOLS								
Variable	**lnBANK**		**lnGDPPC**		**lnENU**		**lnRENE**	
Panel	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**
	-0.625***	0.000	1.267***	0.000	-1.301***	0.000	-1.370***	0.000

Note: *** denotes significance at the 1% level

Source: authors

The results of the coefficient estimation tests applied to the model are shown in Table 8. According to these results, it is understood that the outcomes from the *FMOLS* and *DOLS* methods are consistent. When the results are examined, both tests show that banking sector development *(lnBANK)* has a statistically significant and negative effect on *CO2* emissions. This result indicates that banking sector development contributes positively to the reduction of environmental pollution. Furthermore, the results reveal that energy use *(lnENU)* and renewable energy consumption *(lnRENE)* also have a reducing effect on CO2 emissions. Finally, the results suggest that for the 26 OECD member countries, economic growth *(lnGDPPC)* has a positive impact on environmental pollution.

After examining the cointegration relationship between the variables, the causal relationship was analyzed using the Dumitrescu-Hurlin (2012) causality test.

Table 9. Dumitrescu-Hurlin panel causality test results

Null (H_0) Hipotez	Wald Statistic	Z-bar Statistic	Prob.
lnBANK $\nrightarrow$ lnCO2	4.988***	4.904	0.000
lnCO2 $\nrightarrow$ lnBANK	5.835***	6.468	0.000
lnGDPPC $\nrightarrow$ lnCO2	7.555***	9.644	0.000
lnCO2 $\nrightarrow$ lnGDPPC	2.585	0.466	0.642
lnENU $\nrightarrow$ lnCO2	3.475**	2.108	0.035
lnCO2 $\nrightarrow$ lnENU	4.439***	3.889	0.000
lnRENE $\nrightarrow$ lnCO2	7.940***	10.355	0.000
lnCO2 $\nrightarrow$ lnRENE	4.480***	3.964	0.000

Note:** *, *, and * denote significance at the 1%, 5%, and 10% levels, respectively*

Source: authors

Examining Table 9, which contains the results of the Dumitrescu-Hurlin (2012) panel causality method, a bidirectional causality is found between banking sector development and *CO2* emissions. Other results in the table show a bidirectional relationship between energy use, renewable energy consumption, and CO2 emissions, and the null hypothesis is rejected. Another finding reveals a unidirectional causality relationship from economic growth to CO2 emissions.

DISCUSSION

This study examines the impact of banking sector development on CO2 emissions in OECD countries for the 2001–2021 period, using modern panel data techniques. The findings provide significant contributions to the core debates in the literature regarding the environmental role of the banking sector. The most important result of the study is that the development of the banking sector significantly reduces CO2 emissions. This indicates that banks in OECD countries are undertaking a role that improves environmental quality by directing their resources toward green technologies and sustainable projects rather than carbon-intensive sectors. This finding confirms the real-economy impact of sustainability-focused practices, such as Environmental, Social, and Governance (ESG) criteria.

Other findings show that economic growth increases emissions, while renewable energy consumption decreases them. The causality analysis revealed a bidirectional feedback mechanism between banking development and CO2 emissions, and a unidirectional relationship from economic growth to emissions. A significant consistency in the findings can be observed when comparing the results with studies in the literature. The most striking finding of this study is that banking sector development (lnBANK) has a negative and significant effect on CO2 emissions. This finding suggests that the banking sector in OECD countries plays a role in enhancing environmental quality by directing funds towards green technology and sustainable projects rather than carbon-intensive industries. These findings are supported by the works of Aras and Kazak (2022) and Shabir et al. (2024), who suggest that banks that adopt ESG criteria in their lending practices successfully reduce the ecological footprint. This suggests that the "green banking" mechanism may be more dominant in the OECD, which is contrary to the finding by Rădulescu et al. (2022) that banking expansion increases the ecological footprint. Subsequently, the fact that economic growth (lnGDPPC) increases CO2 emissions is consistent with arguments within the framework of the Environmental Kuznets Curve (EKC) hypothesis.

This result suggests that OECD countries as a panel have not yet fully transitioned to a growth path that reduces emissions and are in the increasing segment of the EKC during the period under review. This finding is consistent with studies by Acheampong (2019) and Apergis and Ozturk (2015) questioning the validity of the EKC hypothesis for CO2 or finding that the turning point occurs at high income levels. Finally, consistent with expectations, the fact that renewable energy consumption (lnRENE) reduces emissions confirms a broad consensus in the literature (Samour et al., 2022; Mehmood, 2023). This result is consistent with studies showing a reciprocal causal relationship between banking growth, energy consumption, and CO2 emissions like Shahbaz et al., 2013; Al-Mulali et al., 2015, who find a mutual feedback mechanism between financial development, energy consumption, and environmental degradation. On the other hand, our results are inconsistent with studies (e.g., Sadorsky, 2010) that only find a unidirectional effect between financial development and emissions. In particular, the reciprocal causal relationship between banking development and CO2 emissions suggests that these two variables influence each other. While the banking industry influences environmental quality through financial decisions (lnBANK → lnCO2), increasing environmental concerns and regulations also influence banking practices (e.g., adoption of ESG standards) (lnCO2 → lnBANK). The unidirectional causal relationship between economic growth and emissions (lnGDPPC → lnCO2) supports the "growth-related emissions" hypothesis proposed in the literature and confirms that economic activity is the primary driver of environmental degradation. The lack of a causal relationship between CO2 emissions and economic growth can be explained by the fact that environmental policies implemented in OECD countries during the study period did not statistically significantly hinder economic growth.

CONCLUSION

This study examines the impact of banking sector development, economic growth, energy use, and renewable energy consumption on CO2 emissions in 26 OECD countries over the period 2001–2021. Utilizing panel data econometric techniques, including Pedroni and Kao cointegration tests, FMOLS and DOLS estimators, and Dumitrescu-Hurlin causality tests, the results reveal that banking sector development and renewable energy consumption significantly reduce CO2 emissions, whereas economic growth increases them. Furthermore, the causality analysis confirms bidirectional relationships between banking development, renewable energy consumption, and CO2 emissions.

These findings indicate that the banking sector in OECD countries contributes to environmental quality through a “technical and structural effect,” suggesting that financial development can support the transition toward sustainable investment rather than carbon-intensive activities. This finding also highlights the potential real-economy effects of sustainability-oriented practices, including ESG integration. For policymakers, the results emphasize the importance of leveraging the financial system as a catalyst for the green transition. Strengthening regulatory tools such as climate stress testing, providing tax incentives for green investments, and integrating ESG criteria into banking regulations may help align financial development with environmental objectives and reduce the environmental costs of economic growth.

While this study provides empirical evidence on the banking-environment nexus, its focus on OECD countries represents a limitation. Future research should include developing and emerging economies to enable comparative analysis and incorporate micro-level banking data to examine how specific financial instruments influence environmental sustainability. Overall, the findings suggest that a well-regulated and sustainability-oriented banking sector can play an important role in supporting the transition toward a low-carbon economy.

Declaration of Research and Publication Ethics

This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement

1. Author: Incorporation of intellectual content, study concept, reviewing the manuscript.

2. Author: Data collection, data interpretation, methodology, original draft preparation.

3. Author: Theoretical background, proofreading, critical revision.

4. Author: Proofreading, critical revision.

Declaration of Researcher's Conflict of Interest

There is no potential conflicts of interest in this study.

LITERATURE

Acheampong, A.O. (2019). Economic growth, CO2 emissions and energy consumption: What causes what and where? *Energy Economics,* 74, 677-692.

Adams, S., & Klobodu, E. K. M. (2018). Financial development and environmental degradation: Does political regime matter? Journal of Cleaner Production, 197, 1472-1479

Ahad, M., Dar, A. A., & Imran, M. (2019). Does financial development promote industrial production in Pakistan? Evidence from combined cointegration and causality approach. *Global Business Review*, 20(3), 676-692. Doi:10.1177/0972150918825208

Al-Mulali, U., Tang, C. F., & Ozturk, I. (2015). Does financial development reduce environmental degradation? Evidence from a panel study of 129 countries. Environmental Science and Pollution Research, 22(19), 14891-14900.

Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. Energy Policy, 38(1), 656-660.

Apergis, N. and Ozturk, I. (2015). Testing the environmental Kuznets curve hypothesis in Asian countries. *Ecological Indicators,* 52, 16-22.

Aras, G., Kazak, E.H. (2022). Enhancing firm value through the lens of esg materiality: Evidence from the banking sector in OECD countries. *Sustainability,* 14(22), 15302.

Baltagi, B.H. (2005). Econometric analysis of panel data, 3rd Edition, John Wiley and Sons, Ltd. England, 40.

Bank of Canada (BoC). (2025). Climate Scenario Analysis and Financial Stability.

Bank of Japan (BoJ). (2025). Low-interest loan program for green investments.

Beka, A. and Abazi-Alili, H. (2024). Role of banking sector performance in renewable energy consumption: A comparative analysis of OECD countries and the western balkans. *International Journal of Sustainable Development and Planning,* 19(7), 2709-2718.

Bolton, P., Despres, M., Pereira da Silva, L.A., Samama, F. & Svartzman, R. (2020). The green swan: Central banking and financial stability in the age of climate change. Bank for International Settlements.

Celik, M.Y. and Unsur, Z. (2020). Determining the relationship between globalization and growth by dumitrescu-hurlin panel causality test. *İzmir Journal of Economics,* 35(1), 201-210.

Dang, V. T. and Dang, W.V.T. (2019). Multi-criteria decision-making in the evaluation of environmental quality of OECD countries. *International Journal of Ethics and Systems,* 36(1), 119-130. https://doi.org/10.1108/ijoes-06-2019-0101

Dogan, E. and Seker, F. (2016). Determinants of CO2 emissions in the European Union: The role of renewable and non-renewable energy. *Renewable Energy,* 94, 1-10.

Dumitrescu, E.I. and Hurlin C. (2012). Testing for Granger non-causality in heterogeneous panels. *Economic Modelling,* 29(4), 1450-1460.

Ganda, F. (2019). The environmental impacts of financial development in OECD countries: a panel GMM approach. Environmental Science and Pollution Research, 26(7), 6758-6772. https://doi.org/10.1007/s11356-019-04147-z

Grossman, G.M. and Krueger, A.B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics,* 110(2), 353–377. https://doi.org/10.2307/2118443

Halkos, G. and Polemis, M. (2017). Does financial development affect environmental degradation? Evidence from the OECD countries. *Business Strategy and the Environment,* 26(8), 1162-1180. https://doi.org/10.1002/bse.1976

Haug, A. A., & Ucal, M. (2019). The role of trade and FDI for CO2 emissions in Turkey: Nonlinear relationships. Energy Economics, 81, 297-307

Im, K.S., Pesaran, M.H. & Shin, Y. (2003). Testing for unit roots in heterogeneous panels.

Journal of Econometrics, 53-74.

International Energy Agency (IEA). (2025). Global energy and CO2 emissions report 2025. Paris: IEA. Retrieved from https://www.iea.org/

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of Econometrics,* 90(1), 1-44.

KfW Bankengruppe. (2025). Green loans and sustainability strategy. Retrieved from https://www.kfw.de/

Korea's GND. (2020). Korean Green New Deal framework.

Levin, A., Lin, C.F. & Chu, C. (2002). Unit root test in panel data: Asymptotic and finite sample properties. *Journal of Econometrics*, 108, 1–25.

Li, C. and Ayub, B. (2025). The green response of financial ınclusion, ınfrastructure development and renewable energy to the environmental sustainability: A newly evidence from OECD economies. *Plos One,* 20(1), e0314731.

Mahmood, H. (2009). The energy consumption and economic growth nexus: The neutrality hypothesis. *Journal of Environmental and Economic Studies*, 1(2), 45-56.

Mehmood, U. (2023). Environmental sustainability through renewable energy and banking sector development: policy implications for N-11 countries. *Environmental Science and Pollution Research,* 30(9), 22296-22304.

Nazlıoglu, S. (2010). Makro iktisat politikalarının tarım sektörü üzerindeki: gelişmiş ve gelişmekte olan ülkeler için bir karşılaştırma. Yayımlanmamış Doktora Tezi, Erciyes Üniversitesi Sosyal Bilimler Enstitüsü, Kayseri, 98.

OECD. (2018). Climate scenarios and stress tests: A global perspective. Paris: OECD Publishing.

OECD. (2020). Green Finance and Investment Centre: Mobilising finance for environmental sustainability. Paris: OECD Publishing. Retrieved from https://www.oecd.org/cgfi/

OECD.(2025). Member countries. Retrieved fromhttps://www.oecd.org/about/members-and-partners/

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics,* 61(1), 653- 570.

Pedroni, P. (2000). Fully modified ols for heterogeneous cointegrated panels, in Baltagi, Badi H. (Ed.), nonstationary panels, panel cointegration and dynamic panels (Advances in Econometrics), New York: Elsevier Science Inc. 93–130.

Pedroni, P. (2001). Purchasing power parity tests in cointegrated panels. *Review of Economics* *and Statistics,* 83, 727-931.

Pedroni, P., (2004). Panel cointegration, asymptotic and finite sample properties of pooled time series tests with an application to the purchasing power parity hypothesis. *Econometric Theory*, 20(3), 597-625.

Ren, S., Hao, Y., & Wu, H. (2022). How does green investment affect environmental pollution? Evidence from China. Environmental and Resource Economics, 81(1), 25-51.

Rădulescu, M., Balsalobre-Lorente, D., Joof, F., Samour, A. & Tursoy, T. (2022). Exploring the Impacts of banking development, and renewable energy on ecological footprint in OECD: New evidence from method of moments quantile regression. *Energies,* 15(24), 9290. https://doi.org/10.3390/en15249290

Sadorsky, P. (2010). The impact of financial development on energy consumption in emerging economies. *Energy Policy,* 38(5), 2528-2535.

Samour, A., Delani M. & Tursoy, T. (2022). Renewable energy, banking sector development, and carbon dioxide emissions nexus: A path toward sustainable development in South Africa. *Renewable Energy,* 193,1032-1040.

Sendeniz-Yuncu, I., Akdeniz, L. & Aydogan, K. (2008). Interdependence of the banking sector and the real sector: Evidence from OECD countries. *Applied Economics,* 40(6), 749-764. https://doi.org/10.1080/00036840600735424

Shabir, M., Isık, O., Hashmi, S. H. & Mujtaba, G. (2024). Impact of ESG practices on european bank lending for sustainability: The role of culture and institutions.

Shahbaz, M., Tiwari, A. K., & Nasir, M. (2013). The effects of financial development, economic growth, coal consumption and trade openness on CO2 emissions in South Africa. Energy Policy, 61, 1452-1459. https://doi.org/10.1016/j.enpol.2013.07.006

Shahbaz, M., Nasir, M. A., & Roubaud, D. (2018). Environmental degradation in France: The effects of FDI, financial development, and energy innovations. Energy Economics, 74, 843-857. https://doi.org/10.1016/j.eneco.2018.07.020

Shahbaz, M., Abro, A. A., Alam, N., Murshed, M., Mahmood, H. & Musah, M. (2023). Financial development and green growth from a global perspective: a dynamic panel threshold analysis. Environment, Development and Sustainability, 1-28.

Stock, J. H. and Watson, M.W. (1993). A simple estimator of cointegration vectors in higher order integrated systems. *Econometrica,* 61, 783-820.

Sveriges Riksbank. (2020). Exclusion of carbon-intensive bonds from the foreign exchange reserves. Stockholm: Sveriges Riksbank.

Tamazian, A., Chousa, J.P. & Vadlamannati, K.C. (2009). Does higher economic and financial development lead to lower carbon emissions? *Energy Policy,* 37(1), 246-253.

Umar, M., & Safi, A. (2023). Do green finance and innovation matter for environmental protection? A case of OECD economies. Energy Economics, 119, 106560.

Wang, Q., Ge, Y. & Li, R. (2023). Does improving economic efficiency reduce ecological footprint? the role of financial development, renewable energy, and ındustrialization. *Energy & Environment,* 36(2), 729-755. https://doi.org/10.1177/0958305x231183914

World Commission on Environment and Development (WCED). (1987). Our common future. Oxford: Oxford University Press

World Bank. (2016). World development indicators 2016. Washington, DC

World Bank. (2018). World development indicators 2018. Washington, DC

Yang, Y., Su, X., & Yao, S. (2021). Nexus between green finance, sustainable development and CO2 emissions: A cross-country analysis. *Journal of Cleaner Production*, 290, 125187. https://doi.org/10.1016/j.resourpol.2021.102445

Zhang, Y. J. (2011). The impact of financial development on carbon emissions: An empirical analysis in China. *Energy Policy,* 39(4), 2197-2203.

https://www.oecd.org/about/members-and-partners/, unepfi.org,
finance.ec.europa.eu/sustainable, equator-principles.com, ngfs.net, fsb-tcfd.org,
www.worldbank.org, climatebonds.net, bis.org