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Financial Development, Oil Prices, and Environmental Outcomes: Panel Evidence

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Abstract

Introduction: This study analyzed the impacts of economic development, energy consumption, financial development, and oil prices on carbon emissions using panel data from 11 countries from January 1, 1990, to June 1, 2025.

Methods: To investigate the interactions among the variables, advanced econometric methods, including Pedroni's and Westerlund's Bootstrap cointegration tests, FMOLS-DOLS, and CCE-MG, were employed to obtain comprehensive and reliable results.

Results: The findings indicate that energy consumption has the most significant positive effect on carbon emissions, while economic growth and financial development negatively influence carbon emissions.

Conclusion: The results suggest that economic growth and financial development have both positive and negative effects on the environment, reflecting the complex interactions between technological advancements, structural economic shifts, and policy measures. Moreover, a negative correlation between crude oil prices and carbon emissions indicates that increasing oil prices drive a partial demand shift toward alternative energy sources, particularly in the industrial and automotive sectors; however, this effect varies across models and specifications. These findings provide practical insights for policymakers regarding environmental sustainability, sustainable economic development, and energy policy, emphasizing the need for targeted monitoring and feasible implementation mechanisms, especially in developing countries.

Keywords: Economic development, Industry, Carbon dioxide, Oil prices, Carbon emissions

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Introduction

Over the past three decades, profound changes in financial systems and global energy markets have underscored the growing importance of environmental sustainability. Two critical issues—ensuring energy security and addressing climate change—have spurred efforts toward achieving net-zero carbon targets, while simultaneously highlighting the need to ensure the sustainability of economic development. To address the growing concern of environmental sustainability, this study seeks to answer the following research question: Can financial systems mitigate the environmental impacts of energy price shocks? Understanding this process is of great significance for both academic literature and policy development, particularly in the current economic climate characterized by persistent increases in fossil fuel prices. Notably, significant price volatility in crude oil markets has substantial implications for both environmental sustainability and energy security.

During the same period, the deepening of financial systems, driven by rapid technological advancements, has directly influenced the direction and environmental impacts of energy investments (1). While financial development facilitates the adoption of environmentally friendly technologies, unplanned increases in production capacity can exacerbate emissions. Consequently, whether financial systems serve as a buffer against environmental shocks remains a pertinent research question. Developed economies such as the United States, Germany, the United Kingdom, and Japan have maintained high and stable levels of financial development, whereas countries like Italy, Mexico, and Turkey show lower performance and more volatile trajectories. These differences influence how financial systems can mitigate environmental shocks and affect carbon emissions, highlighting the importance of well-designed financial policies for sustainable development.

A review of the relevant literature reveals numerous studies examining the relationship between energy consumption, economic growth, and environmental degradation (2-4). However, research exploring how financial development mitigates the impact of energy price volatility on carbon emissions remains relatively limited (5, 6). Although the literature has typically addressed the effects of financial development and energy prices on carbon emissions separately, the interaction between these factors has been insufficiently explored. While recent studies have begun to address this gap (7, 8), comprehensive analyses that account for econometric challenges such as cross-sectional dependence and heterogeneity remain scarce. This study aimed to fill this gap and provide a novel perspective to the literature.

Theoretically, the environmental impacts of financial development manifest through various channels (9). First, advanced financial markets facilitate access to clean technologies and renewable energy investments, enabling the substitution of fossil fuels. Second, robust financial systems, through credit and insurance mechanisms, allow firms to withstand energy price shocks without harming the environment (10). Third, in countries with significant financial depth, regulatory and supervisory institutions, along with investor pressures, promote adherence to environmental, social, and governance (ESG) principles (11).

To this end, this study analyzed the effects of economic growth, financial development, and oil price fluctuations on carbon emissions using data from 11 countries—both developed and developing economies—including the United States of America, Germany, Australia, the United Kingdom, France, South Korea, Italy, Japan, Canada, Mexico, and Turkey from 1990 to 2025. The selected countries exhibit diversity in financial development, energy dependency, and environmental regulations to enhance the external validity of the findings.

To determine the characteristics of the variables and select the appropriate analytical approach, Pesaran's (12) CD test was applied to assess cross-sectional dependence, and the IPS (13) unit root test was used to evaluate stationarity. Based on the results, long-term relationships among the variables were examined performing Pedroni's (14) and Westerlund's Bootstrap (15) panel cointegration tests. Subsequently, FMOLS and DOLS (16) methods were employed to estimate the long-run coefficients of the identified relationships, while CCE-MG (12) techniques were used to analyze common shocks and heterogeneity across countries.

This study aimed to contribute to the literature in three aspects. Firstly, by incorporating the relationship between oil prices and economic development into the model, it tests the capacity of financial systems to mitigate the impact of energy price shocks on carbon emissions. Secondly, by including countries with diverse economic structures and long-term data, it seeks to produce generalizable results. Lastly, by employing advanced econometric methods (e.g., Westerlund's cointegration, CCE-MG), it aimed to deliver more reliable findings.

Literature Review

The analysis of the effects of economic growth, energy consumption, and oil prices on environmental sustainability, which forms the focus of this study, has been the subject of numerous studies in recent years, becoming a critical topic for both academic communities and policymakers. The pursuit of achieving both environmental sustainability and economic development simultaneously has led to an increase in multidisciplinary research in this field. A review of the relevant literature reveals that numerous studies have been conducted using different countries and variables. These studies can be summarized under three main headings as follows.

Economic Development and Carbon Emissions

Studies analyzing the relationship between economic development and carbon emissions have found varied results. Pao and Tsai (17) and Mohsin et al. (18) identified a strong causal relationship between energy consumption and carbon emissions. Bunnag (19) and Zubair et al. (20) reported that GDP growth had a positive effect on carbon emissions. Conversely, Habiba and Xinbang (21), Xu et al. (22), Wang et al. (8), and Lv and Li (23) indicated that financial development negatively impacted carbon emissions. In recent years, several studies have emphasized the role of green finance as a mechanism for reducing emissions. Chen and Chen(24) and Ran and Zhang (25) found that the development of green finance significantly contributes to carbon emission reduction, both directly and through channels such as technological innovation and industrial upgrading. Similarly, Zhao et al. (26) and Sun (27) provided evidence that green growth and green finance can mitigate emissions, though their effectiveness varies across regions. Moreover, Sun (27) and Zhang et al. (28) showed that green finance improves carbon emission efficiency, highlighting its potential as a key driver of sustainable development. However, Maji et al. (29), Salahuddin et al. (30), and Patel and Mehta (31) found a positive relationship between financial development and carbon emissions, suggesting that the nexus remains context-dependent.

Oil Price Shocks and Environmental Impacts

The impact of oil price fluctuations on carbon emissions is a frequently explored research topic in the literature. Okwanya et al. (32) found that oil price shocks increased carbon emissions in Africa. Mahajan and Sah (33) examined the impact of oil price shocks on carbon emissions and confirmed their significant effects. Lu et al. (34) identified impacts of oil price shocks on both financial markets and carbon emissions. Chen et al. (24) highlighted the significant influence of renewable energy factors on industrialization, oil prices, and carbon emissions. Haque (35) noted that oil price shocks caused fluctuations in energy demand. Similarly, Zhao et al.(36) analyzed the effects of oil price shocks on renewable energy in China, finding that oil price shocks were significant factors influencing clean energy adoption.

Financial Development and Energy

Another topic increasingly addressed in the literature is whether economic systems can serve as a buffer against environmental shocks. Boufateh and Saadaoui (37) argued that shocks stemming from financial development in Africa affected carbon emissions, while Jarrett et al. (38) demonstrated that countries with robust financial systems were less impacted by energy price shocks. Elzaki (39) found that financial development in Saudi Arabia increased renewable energy demand, with Deka et al. (40) and Murshed and Tanha (41) reporting similar findings for oil-importing countries. Rentschler (42) suggested that renewable energy could serve as an important hedging mechanism against oil price shocks. Additionally, Somoye et al. (43) analyzed the relationship between financial development, income levels, and carbon emissions in Nigeria, concluding that financial development could positively influence environmental performance.

This study aimed to make an original contribution to the literature by analyzing the effects of financial development, energy, and oil prices on carbon emissions using a multidimensional methodology. By employing a comprehensive econometric approach across 11 countries with varying levels of economic development, the study investigated existing gaps in the literature.

Materials and Methods

Materials

The study utilized monthly data from 11 countries with varying levels of development (the United States of America, Germany, Australia, the United Kingdom, France, South Korea, Italy, Japan, Canada, Mexico, and Turkey) covering the period from January 1, 1990, to June 1, 2025. The data were converted into a panel dataset for analysis. Detailed information regarding the variables used in the study is presented in Table 1. Briefly, CO_2 per capita represents carbon dioxide emissions per person, capturing each individual's contribution to total emissions. The Financial Development Index (FDI) is a composite measure of the development of financial institutions and markets, constructed based on depth, access, and efficiency following the IMF and OECD guidelines. Crude Oil Price (Brent) reflects global oil market conditions and serves as a benchmark for energy prices. GDP per capita measures total economic output per person in current USD. Finally, Energy Use per capita indicates primary energy consumption per person (kg oil equivalent), accounting for domestic production, imports, exports, and adjustments for international transport fuels.

Methods

The study aimed to analyze the factors influencing carbon emissions in 11 countries with varying levels of financial development using data spanning from January 1, 1990, to June 1, 2025. To this end, the effects of economic growth, financial development, energy consumption, and oil prices on carbon emissions were investigated. A multidimensional methodological approach was adopted, taking into account the structural characteristics of the dataset. The methodological process is illustrated in Figure 1. The steps outlined in Figure 1 are as follows:

1. Variable Selection and Model Construction: In the initial phase, variables that provide a more comprehensive approach and enhance the reliability of the results were selected to construct the panel data model.
2. Unit Root Testing: Determining the model structure and the appropriate techniques for analysis requires assessing the stationarity of the variables. For this purpose, the IPS unit root test (13) will be employed to evaluate the stationarity levels of the variables.
3. Cross-Sectional Dependence: To examine whether similarities exist among the countries in the panel, Pesaran's (12) CD test will be performed.
4. Panel Cointegration Tests: Cointegration tests are conducted to determine whether long-term relationships exist among the variables in the panel. For this study, Pedroni's (14) and Westerlund's Bootstrap (15) panel cointegration tests will be conducted.
5. Long-Run Estimations: For variables identified as having a cointegration relationship, the FMOLS and DOLS (16) methods will be used to analyze long-run

Table 1. Variables of the Study

Variable	Definition	Short Description	Source	Abbreviation
CO_2 per capita	Carbon emissions per capita	Carbon emissions per person (ton CO_2)	(44)	lnCO_2
Financial Development Index	Financial development index (score ranging from 0 to 1)	A composite index measuring the depth, access, and efficiency of financial institutions and markets	(45)	lnFDI
Crude Oil Price (Brent)	Global crude oil price (USD per barrel)	Global crude oil price (USD per barrel)	(46)	lnBRENT
GDP per capita	Real gross domestic product per capita	Real GDP per person	(44, 47)	lnGDP
Energy Use per capita	Energy consumption per capita (kg oil equivalent)	Energy consumption per person (kg oil equivalent)	(47)	lnEC

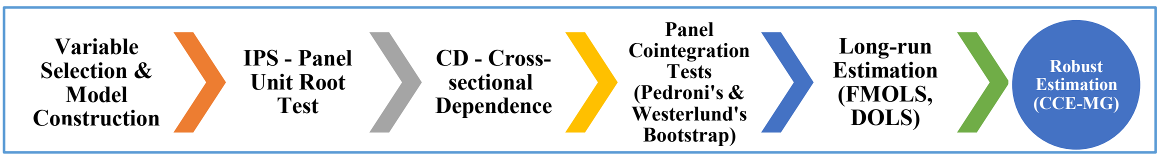

Figure 1. Implementation Process of the Proposed Model

coefficients.

6. Robust Estimation: To account for the potential heterogeneity of the units (countries) or their exposure to common shocks, robust estimation is performed to obtain more reliable results. In this study, cross-sectional dependence among units has been tested. The variables will be tested more robustly according to the CCE-MG (12) framework. CCE-MG is preferred over MG or PMG because it accounts for both cross-sectional dependence and heterogeneity, providing robust long-run estimates under common shocks.

This comprehensive approach ensures more reliable and valid results by considering the structural characteristics of the dataset.

The procedure for implementing the model outlined in Figure 1 was conducted using the following equations.

Cross-Sectional Dependence Testing

To identify potential common shocks among countries, Pesaran's CD (12) test was applied. The implementation of this test utilized Equation 1:

$$CD = \sqrt{\frac{2}{N(N-1)}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}} \tag{1}$$

IPS Unit Root Test

Ensuring the stationarity of variables is critical for obtaining valid and reliable results in panel data analyses. In this study, the IPS unit root test (13) was employed to assess the stationarity levels of the variables. The implementation process is presented in Equation 2:

$$\Delta y_{it} = a_i + p_i y_{it-1} + \sum_{j=1}^{p}\theta_{ij}\Delta y_{it-j} + \varepsilon_{it} \tag{2}$$

Cointegration Tests

To examine long-term relationships among the analyzed variables, Pedroni's (14) and Westerlund's Bootstrap cointegration tests (15) were performed. Equation 3 represents Pedroni's cointegration method, while Equation 4 represents Westerlund's Bootstrap cointegration method:

$$y_{it} = a_i + \delta_i t + \beta_i x_{it} + \varepsilon_{it} \tag{3}$$

$$Z(M) = \frac{1}{N}\sum_{i=1}^{N}\sum_{J=1}^{M}\sum_{t=T_{ij-1}+1}^{T_{ij}}\left(\frac{S_{it}^2}{T_{ij}-T_{ij}-1}\right)^2\frac{1}{\sigma^2} \tag{4}$$

Long-Run Coefficient Estimations (FMOLS and DOLS)

The long-run effects among variables identified as having a cointegration relationship were analyzed using the FMOLS (Equation 5) and DOLS (Equation 6) methods:

$$\hat{\beta}_{FMOLS} = \left(\sum x_{it}^{*}x_{it}^{*\prime}\right)^{-1}\left(\sum x_{it}^{*}y_{it}^{*}\right) \tag{5}$$

$$y_{it} = a_i + \beta_i x_{it} + \sum_{j=-q}^{q}\gamma_{ij}\Delta x_{it-j} + \varepsilon_{it} \tag{6}$$

CCE-MG Analysis

Considering the heterogeneity and cross-sectional dependence characteristics of the panel, the CCE-MG (12) analysis was conducted using the formula in Equation 7:

$$\hat{\beta}_{CCE-MG} = \frac{1}{N}\sum_{i=1}^{N}\hat{\beta}_i \tag{7}$$

All statistical analyses were conducted using Stata 15 and GAUSS 21 to ensure the reproducibility and reliability of the results.

Results

This section presents and interprets the results of the empirical analyses conducted on the dataset. The findings encompass the results of cross-sectional dependence tests, unit root tests, analysis of long-term relationships, and estimations of the direction and magnitude of these relationships. The methods applied were selected by considering the structural characteristics of the model, such as cross-sectional dependence and heterogeneity, to ensure the derivation of valid and reliable results for both econometric analysis and policymakers.

The results, obtained following the implementation steps outlined in Figure 1, are presented in Table 2. According to the Pesaran's CD test (12) results shown in Table 2, the variables lnCO_2, lnGDP, lnEC, and lnBRENT exhibit significant cross-sectional dependence ($P>0.01$), while the lnFDI variable does not. This finding indicates that the countries included in the analysis share structural similarities or are simultaneously exposed to external shocks. Consequently, the use of methods that account for cross-sectional dependence is critical for evaluating the analysis results in the subsequent sections of the study.

The results of the IPS unit root test (13) are presented in Table 3. According to the analysis, the lnFDI variable is stationary at level -I(0)-, while the lnCO2, lnGDP, lnEC, and lnBRENT variables are stationary at the first difference -I(1)-.

According to the Pedroni's cointegration test (14) results presented in Table 4, Panel PP and Panel ADF tests yielded significant results, indicating the presence of a long-term relationship (cointegration) across the panel.

The results of Westerlund's Bootstrap analysis (15), presented in Table 5, indicate significant relationships between the lnGDP, lnEC, and lnFDI variables and the lnCO2 variable. These significant relationships demonstrate that economic growth, financial development, and energy consumption move in tandem with carbon emissions in the long run.

Table 6 presents the results of the FMOLS and DOLS (16) tests. The findings indicate that an increase in energy consumption is associated with higher carbon emissions, while economic growth and financial development are associated with lower carbon emissions. These results reflect long-run associations rather than causal effects and suggest that economic and financial developments are generally linked to environmental improvements.

According to the CCE-MG (12) analysis results presented in Table 7, all independent variables have a statistically significant impact on carbon emissions. Economic growth and financial development are associated with environmental improvements. The effect of crude oil prices (BRENT) varies across model specifications, indicating sensitivity to model choice. Conversely, the positive effect of energy consumption on carbon emissions indicates that a fossil fuel-dominated energy structure may have adverse environmental impacts.

According to the CCE-MG results, per capita energy consumption (EC) is the most significant determinant of carbon emissions, exhibiting positive and highly significant effects. Economic growth (GDPPc) and financial development (FDI) have negative and significant effects; however, the economic magnitude of GDP's effect is very small (-0.0003), suggesting that its practical impact is limited despite statistical significance. Financial development (FDI) is associated with a reduction in carbon emissions, consistent with some studies, although other research suggests that foreign investment may increase pollution in line with the Pollution Haven Hypothesis. This highlights the heterogeneous effects of FDI. Overall, these findings provide a meaningful alternative to the traditional claim that "growth and financial development = increased carbon emissions" and underscore the importance of sustainable development policies.

Discussion

Upon comparison with existing literature, the results of this study indicate that the positive relationship between "environmental pollution and growth," as noted in the studies by Ang (48) and Narayan and Narayan (49), has undergone a transformation in recent years, largely due to the influence of green growth policies. Similarly, the finding reported by Zhang et al.,(7) that financial development can mitigate the relationship between oil prices and carbon emissions aligns with this study's conclusion that financial systems may serve as a balancing mechanism against environmental shocks.

Moreover, while Wang et al. (8) argued that the level of financial development in countries impacted carbon emissions in varying directions (positive or negative), Dimnwobi et al. (50) and Xu et al. (22) advocated the thesis of "environmental sustainability through green finance." Similarly, this study finds that financial development has a negative effect on carbon emissions, providing a comprehensive perspective that reconciles divergent views in the literature. I observe that the negative relationships between economic growth, financial development, and carbon emissions may be influenced by environmental policies, technological advancements, or structural economic changes in the studied countries.

Table 2. CD Test Results

Variable	CD Statistic	*P*-value	Interpretation
$lnCO_2$	6.673	0.000	Exists
lnGDP	5.704	0.000	Exists
lnEC	4.784	0.001	Exists
lnBRENT	4.172	0.000	Exists
lnFDI	1.578	0.175	Not Exist

Table 3. IPS Unit Root Test Results

Variable	Level (*P*-value)	First Difference (*P*-value)	Stationarity Order
$lnCO_2$	0.8958	0.0000	I (1)
lnGDP	0.7965	0.0000	I (1)
lnEC	0.9337	0.0000	I (1)
lnBRENT	0.8957	0.0000	I (1)
lnFDI	0.0006	–	I (0)

Table 4. Pedroni's Panel Cointegration Test Results

Test	*P*-value	Interpretation
Panel v-Statistic	0.7431	Not significant
Panel rho-Statistic	0.2715	Not significant
Panel PP-Statistic	0.0000	Significant
Panel ADF-Statistic	0.0457	Significant at 5% level

Table 5. Westerlund's Bootstrap Panel Cointegration Test

Variable	LM Statistic	Bootstrap *P*-value	Asymptotic *P*-value	Result
lnGDP	4.890	0.038	0.000	+
lnEC	5.177	0.031	0.000	+
lnBRENT	4.587	0.301	0.000	–
lnFDI	4.122	0.045	0.000	+

Table 6. FMOLS and DOLS Estimation Results

Method	Variable	Coefficient	Std. Error	t-Statistic	*P*-value
FMOLS	lnEC	1.120	0.044	22.90	0.0000
FMOLS	lnGDP	-0.178	0.062	-2.87	0.0043
FMOLS	lnFDI	-0.093	0.047	-1.97	0.0490
DOLS	lnEC	1.087	0.051	17.14	0.0000
DOLS	lnGDP	-0.202	0.067	-3.01	0.0028
DOLS	lnFDI	-0.088	0.043	-2.04	0.0410

Table 7. CCE-MG Estimation Results

Variable	Coefficient	t-Statistic	Approx. *P*-value
lnGDP	-0.0003	-2.41	>0.05
lnEC	0.0012	2.36	>0.05
lnBRENT	-0.2730	-2.77	>0.05
lnFDI	-0.0002	-2.05	>0.05

Another significant finding of this study is the negative effect of crude oil prices on carbon emissions. This result suggests that increasing oil prices may lead to reduced carbon emissions by driving a shift toward alternative energy sources in sectors such as transportation and industry. This finding is consistent with the findings of Vo and Vo (51), who noted that carbon emissions influenced economic growth, and Mahajan and Sah (33), who highlighted the significant impact of oil price shocks on carbon emissions.

Limitations and Potential Research Errors

This study provides valuable insights into the relationship between financial development, oil prices, and environmental sustainability; however, several potential sources of research error should be acknowledged. The analysis relies on secondary data from international databases such as the World Bank and the EIA, which may include inconsistencies, missing observations, or subsequent revisions that could affect result precision. Additionally, while the Westerlund cointegration and CCE-MG estimators were employed to minimize bias, possible specification errors, omitted variables, or endogeneity issues cannot be completely ruled out. The model also may not fully capture the country-specific institutional or policy dynamics that influence environmental outcomes. Furthermore, the interpretation of causality should be made with caution, as the empirical design primarily reflects associations rather than strict causal relationships. Future research could reduce these limitations by incorporating broader datasets, nonlinear models, and additional institutional indicators to improve robustness and explanatory depth.

Conclusion

In the 21st century, amidst escalating climate change and environmental crises, achieving environmental sustainability has become a critical issue. Numerous economic, technological, and scientific innovations have not only generated added value but also introduced new risk factors into daily life. Consequently, one of the most debated topics of this century has been the simultaneous achievement of economic development and environmental sustainability. To this end, this study analyzes the impacts of per capita income, energy consumption, financial development, and oil prices on carbon emissions using a dataset (monthly data) spanning from January 1, 1990, to June 1, 2025, across 11 countries with varying levels of economic development. Considering the characteristics of the dataset, Westerlund's Bootstrap cointegration test (15) was employed, and long-term relationships among the variables were tested using the FMOLS, DOLS (16), and CCE-MG (12) methods.

Based on the findings shown in Tables 5 to 7, the following conclusions can be drawn:

1. Aligning financial systems with environmental sustainability programs is a critical tool for reducing carbon emissions. To this end, the development of green bonds, ESG-focused investment funds, and sustainable finance frameworks should be prioritized.
2. Restructuring growth policies with a focus on environmental development is of paramount importance. Environmentally friendly investments, energy efficiency practices, and circular economy models can establish an inverse relationship between economic growth and environmental performance. Although GDP per capita (lnGDP) is statistically significant in the CCE-MG results, its economic magnitude is very small (-0.0003), suggesting limited practical impact.
3. The impact of oil price fluctuations on carbon emissions underscores the need for effective energy price regulations. In this regard, the integration of carbon taxes and carbon emission systems into energy markets is crucial. However, the effect of crude oil prices (BRENT) varies across model specifications, indicating sensitivity to model choice.
4. Policies should be developed at a micro level, considering differences between countries. Particularly in developing economies, directing financial systems toward green investments can amplify their impact on reducing carbon emissions.

In conclusion, this study evaluates the effects of financial development and economic growth on environmental sustainability beyond traditional approaches, offering a novel framework. The advanced econometric analyses employed address methodological gaps in the literature and provide reliable and actionable results for environmental policymakers. Future studies could explore sector-specific disaggregated analyses or methods that account for structural breaks to yield further insights.

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Competing Interests

The authors declare that they have no competing interests.

Ethical Approval

None.

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References

1. Bilgili F, Koçak E, Bulut Ü, Kuşkaya S. Can biomass energy be an efficient policy tool for sustainable development? Renew Sustain Energy Rev 2017;71:830-45. doi:10.1016/j.rser.2016.12.109
2. Stern DI. The rise and fall of the environmental Kuznets curve. World Dev 2004;32(8):1419-39. doi:10.1016/j.worlddev.2004.03.004
3. Apergis N, Payne JE. Energy consumption and economic growth: evidence from the Commonwealth of Independent States. Energy Econ 2009;31(5):641-7. doi:10.1016/j.eneco.2009.01.011
4. Shahbaz M, Lean HH, Shabbir MS. Environmental Kuznets curve hypothesis in Pakistan: cointegration and Granger causality. Renew Sustain Energy Rev 2012;16(5):2947-53. doi:10.1016/j.rser.2012.02.015

5. Tamazian A, Bhaskara Rao B. Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. Energy Econ 2010;32(1):137-45. doi:10.1016/j.eneco.2009.04.004
6. Sadorsky P. Financial development and energy consumption in Central and Eastern European frontier economies. Energy Policy 2011;39(2):999-1006. doi:10.1016/j.enpol.2010.11.034
7. Zhang J, Wang L, Wang S. Financial development and economic growth: recent evidence from China. J Comp Econ 2012;40(3):393-412. doi:10.1016/j.jce.2012.01.001
8. Wang J, Zhang S, Zhang Q. The relationship of renewable energy consumption to financial development and economic growth in China. Renew Energy 2021;170:897-904. doi:10.1016/j.renene.2021.02.038
9. Zeren F, Gürsoy S. The nexus between wind energy consumption, economic growth and financial development: evidence from panel causality and cointegration test with fourier function. Technol Econ Smart Grids Sustain Energy 2022;7(1):31. doi:10.1007/s40866-022-00155-w
10. Apergis N, Christou C, Gupta R. Are there environmental Kuznets curves for US state-level CO2 emissions? Renew Sustain Energy Rev 2017;69:551-8. doi:10.1016/j.rser.2016.11.219
11. Baker M, Bergstresser D, Serafeim G, Wurgler J. Financing the Response to Climate Change: The Pricing and Ownership of US Green Bonds. National Bureau of Economic Research; 2018. doi:10.3386/w25194
12. Pesaran MH. Estimation and inference in large heterogeneous panels with a multifactor error structure. Econometrica 2006;74(4):967-1012. doi:10.1111/j.1468-0262.2006.00692.x
13. Im KS, Pesaran MH, Shin Y. Testing for unit roots in heterogeneous panels. J Econom 2003;115(1):53-74. doi:10.1016/s0304-4076(03)00092-7
14. Pedroni P. Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxf Bull Econ Stat 1999;61(S1):653-70. doi:10.1111/1468-0084.0610s1653
15. Westerlund J. Testing for panel cointegration with multiple structural breaks. Oxf Bull Econ Stat 2006;68(1):101-32. doi:10.1111/j.1468-0084.2006.00154.x
16. Hansen BE, Phillips PC. Estimation and Inference in Models of Cointegration: A Simulation Study. 1988. Available from: https://elischolar.library.yale.edu/cowles-discussion-paper-series/1125.
17. Pao HT, Tsai CM. Multivariate Granger causality between CO2 emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product): evidence from a panel of BRIC (Brazil, Russian Federation, India, and China) countries. Energy 2011;36(1):685-93. doi:10.1016/j.energy.2010.09.041
18. Mohsin M, Naseem S, Sarfraz M, Azam T. Assessing the effects of fuel energy consumption, foreign direct investment and GDP on CO2 emission: new data science evidence from Europe & Central Asia. Fuel 2022;314:123098. doi:10.1016/j.fuel.2021.123098
19. Bunnag T. Analyzing short-run and long-run causality relationship among CO2 emission, energy consumption, GDP, square of GDP, and foreign direct investment in environmental Kuznets curve for Thailand. Int J Energy Econ Policy 2023;13(2):341-8. doi:10.32479/ijeep.14088
20. Zubair AO, Abdul Samad AR, Dankumo AM. Does gross domestic income, trade integration, FDI inflows, GDP, and capital reduces CO2 emissions? An empirical evidence from Nigeria. Curr Res Environ Sustain 2020;2:100009. doi:10.1016/j.crsust.2020.100009
21. Habiba U, Xinbang C. The impact of financial development on CO2 emissions: new evidence from developed and emerging countries. Environ Sci Pollut Res 2022;29(21):31453-66. doi:10.1007/s11356-022-18533-3
22. Xu D, Sheraz M, Hassan A, Sinha A, Ullah S. Financial development, renewable energy and CO2 emission in G7 countries: new evidence from non-linear and asymmetric analysis. Energy Econ 2022;109:105994. doi:10.1016/j.eneco.2022.105994
23. Lv Z, Li S. How financial development affects CO2 emissions: a spatial econometric analysis. J Environ Manage 2021;277:111397. doi:10.1016/j.jenvman.2020.111397
24. Chen J, Wu W, Nguea SM. Combining the effects of industrialization and oil prices on CO2 emissions: what role do renewable energy, urbanization and financial crisis play? Sustain Dev 2025;33(2):2780-96. doi:10.1002/sd.3264
25. Ran C, Zhang Y. The driving force of carbon emissions reduction in China: does green finance work. J Clean Prod 2023;421:138502. doi:10.1016/j.jclepro.2023.138502
26. Zhao J, Taghizadeh-Hesary F, Dong K, Dong X. How green growth affects carbon emissions in China: the role of green finance. Econ Res Ekon Istraz 2023;36(1):2090-111. doi:10.1080/1331677X.2022.2095522
27. Sun C. The correlation between green finance and carbon emissions based on improved neural network. Neural Comput Appl 2022;34(15):12399-413. doi:10.1007/s00521-021-06514-5
28. Zhang W, Zhu Z, Liu X, Cheng J. Can green finance improve carbon emission efficiency? Environ Sci Pollut Res 2022;29(45):68976-89. doi:10.1007/s11356-022-20670-8
29. Maji IK, Habibullah MS, Saari MY. Financial development and sectoral CO2 emissions in Malaysia. Environ Sci Pollut Res 2017;24(8):7160-76. doi:10.1007/s11356-016-8326-1
30. Salahuddin M, Alam K, Ozturk I, Sohag K. The effects of electricity consumption, economic growth, financial development and foreign direct investment on CO2 emissions in Kuwait. Renew Sustain Energy Rev 2018;81(Pt 2):2002-10. doi:10.1016/j.rser.2017.06.009
31. Patel N, Mehta D. The asymmetry effect of industrialization, financial development and globalization on CO2 emissions in India. Int J Thermofluids 2023;20:100397. doi:10.1016/j.ijft.2023.100397
32. Okwanya I, Abah PO, Amaka EO, Ozturk I, Alhassan A, Bekun FV. Does carbon emission react to oil price shocks? Implications for sustainable growth in Africa. Resour Policy 2023;82:103610. doi:10.1016/j.resourpol.2023.103610
33. Mahajan M, Sah DAN. CO2 emissions response to GDP and crude oil price shocks: evidence from India and China using SVAR Model. Sustain Futur 2025;9:100479. doi:10.1016/j.sftr.2025.100479
34. Lu Q, Umair M, Qin Z, Ullah M. Exploring the nexus of oil price shocks: impacts on financial dynamics and carbon emissions in the crude oil industry. Energy 2024;312:133415. doi:10.1016/j.energy.2024.133415
35. Haque MI. Oil price shocks and energy consumption in GCC countries: a system-GMM approach. Environ Dev Sustain 2021;23(6):9336-51. doi:10.1007/s10668-020-01027-y
36. Zhao Y, Zhang Y, Wei W. Quantifying international oil price shocks on renewable energy development in China. Appl Econ 2021;53(3):329-44. doi:10.1080/00036846.2020.1808173
37. Talel B, Zied S. Do asymmetric financial development shocks matter for CO2 emissions in Africa? A nonlinear panel ARDL–PMG approach. Environ Model Assess (Dordr) 2020;25(6):809-30. doi:10.1007/s10666-020-09722-w
38. Jarrett U, Mohaddes K, Mohtadi H. Oil price volatility, financial institutions and economic growth. Energy Policy 2019;126:131-44. doi:10.1016/j.enpol.2018.10.068
39. Elzaki RM. Impact of financial development shocks on renewable energy consumption in Saudi Arabia. Sustainability 2023;15(22):16004. doi:10.3390/su152216004
40. Deka A, Özdeşer H, Seraj M. The impact of oil prices, financial

development and economic growth on renewable energy use. Int J Energy Sect Manag 2023;18(2):351-68. doi:10.1108/ijesm-09-2022-0008
41. Murshed M, Tanha MM. Oil price shocks and renewable energy transition: empirical evidence from net oil-importing South Asian economies. Energy Ecol Environ 2021;6(3):183-203. doi:10.1007/s40974-020-00168-0
42. Rentschler JE. Oil Price Volatility, Economic Growth and the Hedging Role of Renewable Energy. World Bank Policy Research Working Paper No. 6603. Available from: https://ssrn.com/abstract=2326779.
43. Somoye OA, Seraj M, Ozdeser H, Mar'I M. Quantile relationship between financial development, income, price, CO2 emissions and renewable energy consumption: evidence from Nigeria. Lett Spat Resour Sci 2023;16(1):2. doi:10.1007/s12076-023-00330-2
44. World Bank. World Bank Open Data. Washington: World Bank; 2025. Available from: https://data.worldbank.org/.
45. International Monetary Fund (IMF). IMF Data. IMF; 2025. Available from: https://www.imf.org/en/data.
46. US Energy Information Administration (EIA). Data. EIA; 2025. Available from: https://www.eia.gov/.
47. European Commission (EC). Eurostat. EC; 2025. Available from: https://ec.europa.eu/eurostat.
48. Ang JB. CO2 emissions, energy consumption, and output in France. Energy Policy 2007;35(10):4772-8. doi:10.1016/j.enpol.2007.03.032
49. Narayan PK, Narayan S. Carbon dioxide emissions and economic growth: panel data evidence from developing countries. Energy Policy 2010;38(1):661-6. doi:10.1016/j.enpol.2009.09.005
50. Dimnwobi SK, Madichie CV, Ekesiobi C, Asongu SA. Financial development and renewable energy consumption in Nigeria. Renew Energy 2022;192:668-77. doi:10.1016/j.renene.2022.04.150
51. Vo DH, Vo LH. International volatility transmission among income, CO2 emission, non-renewable and renewable energy consumption: which causes which and when? Energy Rep 2022;8:10061-71. doi:10.1016/j.egyr.2022.07.168