Green Finance and Economic Growth in Algeria: An ARDL Approach (1995–2023)

Ben Merzoug Nabil

University Center of Illizi, Algeria

nabil.benmerzoug@cuillizi.dz

Received: 21./06./2026 **Accepted:01/10/2026** **Published: 20/11/.2026**

Abstract:

This study examines the relationship between green finance and economic growth in Algeria over the period 1995–2023. The analysis is motivated by the growing importance of sustainable finance in economies facing structural dependence on hydrocarbons, external vulnerability, and climate-transition pressures. Drawing on endogenous growth theory and ecological modernization theory, the paper evaluates whether green finance can contribute to a more sustainable growth trajectory in Algeria. Methodologically, the study employs the Autoregressive Distributed Lag (ARDL) approach to investigate both short-run dynamics and long-run relationships among real gross domestic product (GDP), a green finance proxy based on renewable energy investment, CO2 emissions, and total exports. The nominal green finance series is converted into real terms using a domestic price deflator before applying the ln(1 + GREEN_REAL) transformation. The Augmented Dickey-Fuller (ADF) test indicates that all variables are integrated of order one, I(1), which supports the use of the ARDL bounds-testing procedure, provided that none of the variables is I(2). The bounds test suggests the existence of a long-run cointegrating relationship among the variables. In addition, the error correction term is negative and statistically significant, indicating convergence toward long-run equilibrium after short-run disturbances. Diagnostic and stability tests suggest that the estimated model is statistically acceptable, while the results remain subject to the limitations of a small annual sample.

The findings support the view that green finance should be considered within Algeria's broader strategy of economic diversification and sustainable development. However, the empirical results should be interpreted with caution, given the proxy nature of the green finance variable and the limited number of control variables included in the baseline specification. Overall, the study contributes to the literature by providing evidence on the macroeconomic relevance of green finance in the Algerian context.

Keywords: Green finance; Economic growth; ARDL model; Algeria; CO2 emissions; Sustainable development.

JEL Classification Codes: Q56; O44; Q43; C22; O55.

1. Introduction

In recent years, green finance has become an increasingly important instrument for promoting sustainable development and supporting the global transition toward low-carbon economies. The concept of economic growth is no longer limited to the quantitative expansion of gross domestic product; rather, it increasingly includes the quality, sustainability, and environmental compatibility of growth. In this context, green finance plays a central role by directing financial resources toward renewable energy projects, clean technologies, energy efficiency, environmentally responsible infrastructure, and low-carbon development strategies.

The importance of green finance is particularly relevant in the Algerian economy. Algeria remains structurally dependent on hydrocarbon revenues, which exposes the economy to oil price fluctuations, external shocks, and macroeconomic instability. This dependence also limits economic diversification and increases the vulnerability of public revenues, exports, and investment dynamics. At the same time, Algeria faces growing environmental and transition-related pressures, especially as international markets move toward stricter climate regulations and carbon-related trade measures. Under these conditions, green finance may represent not only an environmental necessity but also an economic opportunity to support diversification, improve productive efficiency, reduce carbon intensity, and strengthen long-term economic resilience.

Based on this background, the present study examines the relationship between green finance and economic growth in Algeria over the period 1995–2023. The study is grounded in endogenous growth theory and ecological modernization theory, which both suggest that environmental investment can contribute to innovation, productivity improvement, resource efficiency, and sustainable economic transformation. Methodologically, the study uses the Autoregressive Distributed Lag model to analyze both short-run dynamics and long-run equilibrium relationships between real GDP, green finance, CO2 emissions, and total exports. This methodological choice is consistent with the structure of the data in the paper, where the variables are found to be integrated of order one and suitable for ARDL bounds testing.

Research Problem

Despite Algeria's strong potential for renewable energy and the growing global importance of green finance, the Algerian economy remains highly dependent on hydrocarbons and exposed to external shocks. This raises an important question regarding whether green finance can contribute to economic growth and support a more sustainable development path in Algeria. Accordingly, the main research problem can be formulated as follows:

To what extent does green finance affect economic growth in Algeria during the period 1995–2023?

Sub-questions

From the main research problem, the following sub-questions can be derived:

Is there a long-run relationship between green finance and economic growth in Algeria?

What is the short-run effect of green finance on real GDP?

How do CO2 emissions and total exports interact with economic growth in the Algerian economy?

Can green finance contribute to reducing Algeria's dependence on carbon-intensive growth and supporting economic diversification?

Research Hypotheses

To answer these questions, the study is based on the following hypotheses:

H1: There is a long-run equilibrium relationship between green finance and economic growth in Algeria.

H2: Green finance has a positive effect on real GDP in Algeria.

H3: CO2 emissions are significantly associated with economic growth, reflecting the carbon-intensive nature of the Algerian economy.

H4: Total exports have a positive effect on economic growth, given the importance of the external sector in Algeria's macroeconomic performance.

Objectives of the Study

The main objective of this study is to analyze the impact of green finance on economic growth in Algeria during the period 1995–2023. More specifically, the study aims to:

examine the relationship between green finance and real GDP in Algeria;

test the existence of a long-run cointegration relationship among real GDP, green finance, CO2 emissions, and total exports;

estimate the short-run and long-run effects of the explanatory variables on economic growth;

assess the role of green finance as a potential mechanism for sustainable growth and economic diversification;

provide empirical evidence that may support policy discussions on Algeria's transition toward a more resilient and environmentally sustainable growth model.

Importance of the Study

This study is important because it contributes to the literature on green finance and sustainable economic growth, especially in developing and resource-dependent economies such as Algeria. It also has practical relevance, as green finance may help Algeria diversify its economy, support renewable energy and clean technologies, reduce dependence on hydrocarbons, and limit exposure to external and climate-related risks.

Limits of the Study

The study is limited to Algeria during the period 1995–2023 and focuses on real GDP, green finance, CO2 emissions, and total exports using the ARDL model. Its results should be interpreted with caution because green finance is measured through a proxy, and some important variables such as oil prices, public expenditure, foreign direct investment, and gross fixed capital formation are not included.

Previous Studies

Sachs, Woo, Yoshino, and Taghizadeh-Hesary (2019), This study emphasized the role of green finance in achieving sustainable development goals and enhancing energy security. It argued that green finance helps mobilize resources toward renewable energy, green infrastructure, and low-carbon projects. The study concluded that green finance is an essential tool for supporting the transition toward a sustainable and low-carbon economy.

Taghizadeh-Hesary and Yoshino (2019), This study focused on how to encourage private investment in green finance and green energy projects. It found that high initial costs, long payback periods, and investment risks are major obstacles to green investment. The study concluded that financial incentives and risk-sharing mechanisms are necessary to attract private investors to green projects.

Lee and Lee (2022) ,This study examined the relationship between green finance and renewable energy development using worldwide evidence. The results showed that green finance has a positive and significant effect on renewable energy development in both the short and long run. The study also found that innovation strengthens the impact of green finance on renewable energy.

Meo and Abd Karim (2022), This study analyzed the role of green finance in reducing CO2 emissions. Using a quantile-on-quantile regression approach, the authors found that green finance can help reduce carbon emissions, although its effect differs across countries and market conditions. This study supports the idea that green finance can improve environmental performance.

Bouznit and Pablo-Romero (2016), This study investigated the relationship between CO2 emissions and economic growth in Algeria. The results showed a strong link between economic activity, energy consumption, and CO2 emissions. The study concluded that Algeria's growth model remains highly dependent on fossil energy and is therefore carbon-intensive.

Fakher, Ahmed, Alvarado, and Murshed (2022), This study explored the relationship between renewable energy, financial development, environmental quality, trade, foreign direct investment, and economic growth. The findings showed that renewable energy and financial development play an important role in shaping both economic and environmental outcomes. It also indicated that these effects differ across income groups.

Pesaran, Shin, and Smith (2001), This study introduced the ARDL bounds-testing approach for analyzing long-run relationships among economic variables. It showed that the ARDL method is suitable when variables are integrated at I(0) or I(1), provided that none is I(2). This study provides the methodological basis for using the ARDL model in the present research.

2. Data, Variables, and Methodology

This study investigates the impact of green finance on economic growth in Algeria over the period 1995–2023 using the Autoregressive Distributed Lag (ARDL) approach. The ARDL framework is particularly suitable because

it allows the estimation of both short-run dynamics and long-run relationships when the variables are integrated of order zero, I(0), or order one, I(1), provided that none of them is integrated of order two, I(2).

The dependent variable is real gross domestic product (RGDP), used as an indicator of economic growth. The explanatory variables are green finance (GREEN), carbon dioxide emissions (CO2), and total exports (EX). Green finance is operationalized through the annual volume of renewable energy investments in Algeria, compiled from official national renewable-energy investment records and project reports. It is therefore treated as a proxy for environmentally oriented financing and investment activity rather than as a direct measure of the full green finance market. Because the original GREEN series is reported in nominal Algerian dinars, it is converted into real terms using a domestic price deflator before estimation. Since the GREEN series contains zero or near-zero observations during the early years of the sample, especially before the effective expansion of renewable energy investment, the study applies the transformation ln(1 + GREEN_REAL) instead of the conventional natural logarithm. This transformation preserves the monotonic structure of the variable while allowing all observations to be retained in the estimation.

CO2 emissions are measured in metric tons, while total exports are measured in constant US dollars. Real GDP is measured at constant prices in Algerian dinars. The green finance proxy is expressed in real Algerian dinars after deflation, so that monetary variables are interpreted in real terms as far as the available data allow. The data sources and transformations are reported in a separate data-source table to improve transparency and replicability.

The baseline long-run specification is expressed as follows:

$$\ln(RGDP)_t = \alpha_0 + \alpha_1 \ln(1 + GREEN_REAL)_t + \alpha_2 \ln(CO2)_t + \alpha_3 \ln(EX)_t + \varepsilon_t$$

The ARDL representation of the model is given by:

$$\Delta \ln(RGDP)_t = c_0 + \sum_{i=1}^{p} \varphi_i \Delta \ln(RGDP)_{t-i} + \sum_{i=0}^{q1} \theta_i \Delta \ln(1 + GREEN_REAL)_{t-i} + \sum_{i=0}^{q2} \psi_i \Delta \ln(CO2)_{t-i} + \sum_{i=0}^{q3} \omega_i \Delta \ln(EX)_{t-i} + \lambda_1 \ln(RGDP)_{t-1} + \lambda_2 \ln(1 + GREEN_REAL)_{t-1} + \lambda_3 \ln(CO2)_{t-1} + \lambda_4 \ln(EX)_{t-1} + u_t$$

Based on the Akaike Information Criterion (AIC), the optimal lag structure selected for the estimated model is ARDL(1,0,1,1), where p = 1 for real GDP, q1 = 0 for green finance, q2 = 1 for CO2 emissions, and q3 = 1 for total exports.

The empirical strategy follows four main steps. First, the Augmented Dickey–Fuller (ADF) test is applied to examine the stationarity properties of the variables. Second, the ARDL bounds testing approach is used to assess the presence of cointegration among the variables. Third, once cointegration is confirmed, the short-run error correction model (ECM) is estimated. Finally, a set of diagnostic and stability tests, including RESET, Jarque–Bera, CUSUM, and CUSUMSQ, is conducted to evaluate the adequacy and robustness of the model.

Table (01): Definition and Measurement of Variables

Variable	Symbol	Operational Definition / Proxy	Unit of Measurement
Economic Growth	ln(RGDP)	Real gross domestic product; used as a proxy for economic growth.	Constant prices, Algerian dinars
Green Finance	ln(1+GREEN_REAL)	Real renewable energy investment; used as a proxy for green finance.	Constant prices, Algerian dinars
CO2 Emissions	ln(CO2)	Carbon dioxide emissions; used as a proxy for environmental pressure.	Metric tons
Total Exports	ln(EX)	Total exports of goods and services; used as a proxy for external-sector performance.	Constant prices, US dollars

Table (02): Data Sources and Transformations

Variable	Source	Original Unit	Transformation	Replication Note
RGDP	World Bank, World Development Indicators (WDI) / national accounts	Constant local currency	Natural logarithm: ln(RGDP)	Use the same base year across the sample.
GREEN	Ministry of Energy and Renewable Energies; CEREFE official reports; author-compiled annual series.	Nominal Algerian dinars	Deflate using GDP deflator or CPI, then ln(1+GREEN_REAL)	Annual values should accompany the replication file.
CO2	World Bank WDI or Global Carbon Project / Our World in Data CO2 series	Metric tons	Natural logarithm: ln(CO2)	Use one consistent source throughout the sample.
EX	World Bank WDI: exports of goods and services, constant US dollars	Constant US dollars	Natural logarithm: ln(EX)	Prefer constant-price export series to avoid nominal-price effects.

Note. The GREEN series is a proxy for green finance and should not be interpreted as a comprehensive measure of all green bonds, concessional loans, guarantees, or private green financial instruments. The empirical results should therefore be interpreted as evidence on renewable-energy investment as a green-finance channel.

3-Theoretical Framework of Green Finance and Economic Growth

The relationship between green finance and economic growth can be explained through several macroeconomic perspectives that view environmental investment not as a burden on economic performance, but as a potential driver of sustainable growth. In this context, green finance may promote productive efficiency, technological innovation, and structural transformation, particularly in economies seeking to reduce their dependence on carbon-intensive sectors.

3-1 Theoretical Foundations of Green Finance and Economic Growth

Two major theoretical perspectives provide the foundation for understanding the role of green finance in economic growth.

Endogenous Growth Theory emphasizes that long-term economic growth is generated internally through innovation, human capital, and technological progress. From this perspective, green finance can stimulate investment in renewable energy, clean technologies, and research and development (R&D). These investments may improve Total Factor Productivity (TFP) and create new productive capacities, thereby supporting sustainable economic growth beyond the limits of traditional neoclassical models (Lucas, 1988; Romer, 1990). Recent studies also suggest that green finance can support renewable energy development and technological innovation by reducing financing constraints and reallocating capital toward environmentally sustainable sectors (Lee & Lee, 2022; Wang et al., 2025).

Ecological Modernization Theory argues that economic growth and environmental protection are not necessarily contradictory. According to this view, environmental reforms and green investment can enhance economic efficiency by reducing pollution, limiting resource waste, and encouraging cleaner production systems. In this sense, green finance can contribute to a gradual decoupling between economic growth and environmental degradation, improving both the quality and sustainability of development (Mol & Spaargaren, 2000; OECD, 2011). This theoretical view is also consistent with the idea that ecological restructuring of production and consumption can be achieved through technological change, institutional reform, and market-based environmental policies.

3-2 Macroeconomic Transmission Channels

The positive effects of green finance on Gross Domestic Product (GDP) may operate through several macroeconomic channels.

The first channel is the investment and multiplier effect. Green finance can increase capital inflows into renewable energy, green infrastructure, and environmentally sustainable projects. Since such projects are generally capital-intensive, they may raise Gross Fixed Capital Formation (GFCF), create employment opportunities, increase household income, and stimulate aggregate demand, which in turn supports GDP growth. This argument is supported by international evidence showing that clean-energy investment has expanded significantly and that renewable energy sectors generate employment and productive capacity (IEA, 2024; IRENA & ILO, 2025).

The second channel is resource efficiency and cost reduction. Green investments often target energy efficiency, cleaner technologies, and sustainable production methods. Over time, these improvements may reduce production costs and enhance the competitiveness of firms. This can be interpreted as a positive supply-side effect, whereby productivity gains contribute to higher output and lower inflationary pressure. OECD green growth studies emphasize that environmental policy, innovation, and resource efficiency can support growth while preserving the natural assets on which long-term development depends (OECD, 2011).

The third channel is economic diversification and external resilience. In resource-dependent economies, green finance may support the development of new export-oriented sectors such as renewable energy, green hydrogen, and clean electricity. This diversification can reduce excessive dependence on traditional hydrocarbon exports and improve the economy's ability to absorb external shocks related to global commodity price volatility. This is particularly relevant for hydrocarbon-dependent economies, where diversification is often identified as a key condition for more resilient and sustainable growth (World Bank, 2025; IMF, 2025).

3-3 Green Finance and Macroeconomic Uncertainty in Algeria

The relevance of this framework becomes more significant in the Algerian context, where the economy remains highly dependent on hydrocarbon revenues. This dependence increases vulnerability to oil price fluctuations and external economic shocks, making green finance a potentially important instrument for structural transformation. The World Bank notes that Algeria has historically relied on oil and gas for more than 90% of export revenues, while the IMF stresses that diversification and private-sector development remain essential for unlocking Algeria's long-term growth potential (World Bank, 2025; IMF, 2025).

One important issue is structural vulnerability associated with Dutch Disease. Algeria's economic cycles have historically been linked to changes in hydrocarbon markets, which may discourage long-term productive investment outside the energy sector. In this regard, green finance can help redirect financial resources toward non-oil sectors and support a more balanced growth model. This interpretation is consistent with the broader literature on resource dependence, which argues that natural-resource booms may weaken diversification incentives and expose economies to external price shocks (Corden & Neary, 1982; Sachs & Warner, 2001).

Another issue relates to climate and transition risks. As international markets, particularly the European Union, move toward stricter environmental regulations such as the Carbon Border Adjustment Mechanism (CBAM), Algerian exports may face growing competitiveness challenges. The European Commission states that CBAM initially covers carbon-intensive imports such as cement, iron and steel, aluminium, fertilisers, electricity, and hydrogen, while IMF research indicates that CBAM creates reporting obligations and, from 2026, financial obligations linked to the carbon content of imported goods (European Commission, 2026; IMF, 2025). Therefore, green finance can help firms and public institutions adapt to these changes by supporting cleaner production, reducing carbon intensity, and strengthening the long-term competitiveness of the domestic economy.

3-4 Synthesis of the Theoretical Framework

Based on the above discussion, green finance can be viewed as a strategic mechanism that may influence economic growth through investment expansion, productivity improvement, and economic diversification. In the Algerian case, these mechanisms are particularly relevant because of the country's structural dependence on hydrocarbons and its growing exposure to environmental and external market constraints. Therefore, this

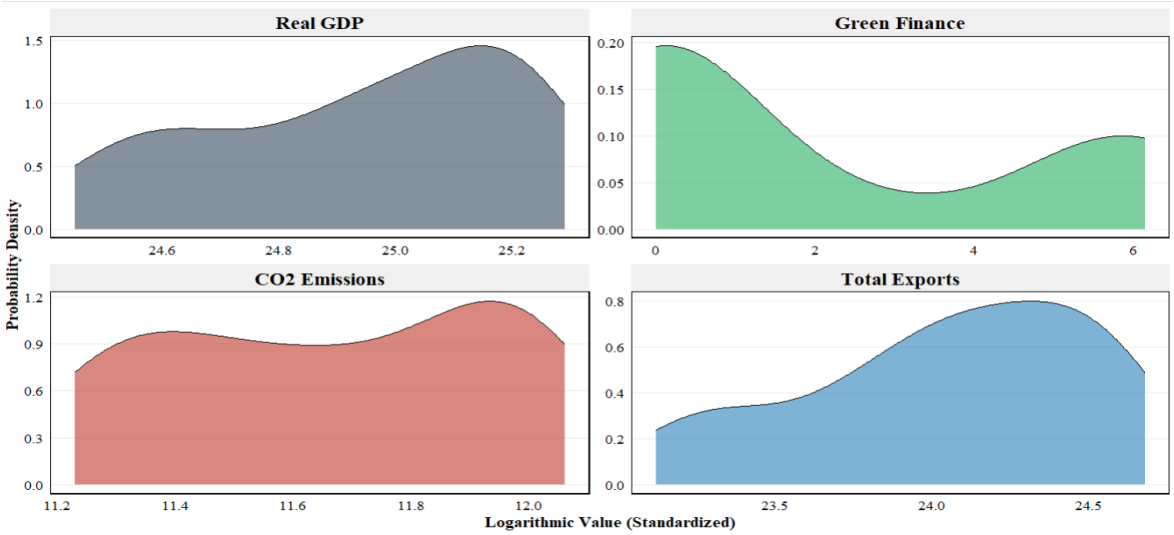
theoretical framework provides a suitable basis for examining the impact of green finance on GDP, while also considering the role of carbon emissions and exports in shaping macroeconomic performance.

4- Descriptive Analysis of the Study Variables

This section presents a descriptive analysis of the study variables before moving to the econometric estimation. It uses density plots, pairwise correlations, comparative boxplots, and a heatmap to summarize the distributional properties and co-movement patterns of the variables over the period 1995-2023. The descriptive evidence is used only as preliminary support for the empirical analysis and should not be interpreted as formal causal evidence.

4-1 Kernel Density Estimation (KDE) of the Statistical Distribution for Macroeconomic Study Variables (Logarithmic Values).

Figure (01): Kernel Density Estimation (KDE) of the Statistical Distribution for Macroeconomic Study Variables (Logarithmic Values).



Source: Author's calculations based on R outputs.

The figure above illustrates the statistical distribution of the study variables using Kernel Density Estimation (KDE), which allows for the observation of the central tendency, dispersion, and skewness characteristics of each individual time series. Through a visual and analytical reading of the curves, the following macroeconomic dynamics can be deduced:

- Real Gross Domestic Product (Real GDP): The GDP curve exhibits a clear negative skewness (left-skewed), where the maximum probability density is concentrated in the upper range of the logarithmic values (between 25.0 and 25.2). This distribution visually reflects the trajectory of continuous economic expansion experienced by the Algerian economy during the study period. It indicates that the economy spent most of the time series in a state of positive growth and accumulation, with a rarity of severe contractionary periods that would otherwise pull the curve toward the lower tail.

- Green Finance: The green finance curve is highly right-skewed. The largest probability mass is concentrated around the logarithmic value of zero, which reflects the absence or very low level of renewable-energy investment during the early part of the sample. The gradual rise of the curve between values of approximately 4 and 6 suggests, at a descriptive level, a delayed expansion of green investment rather than a smooth historical accumulation process.

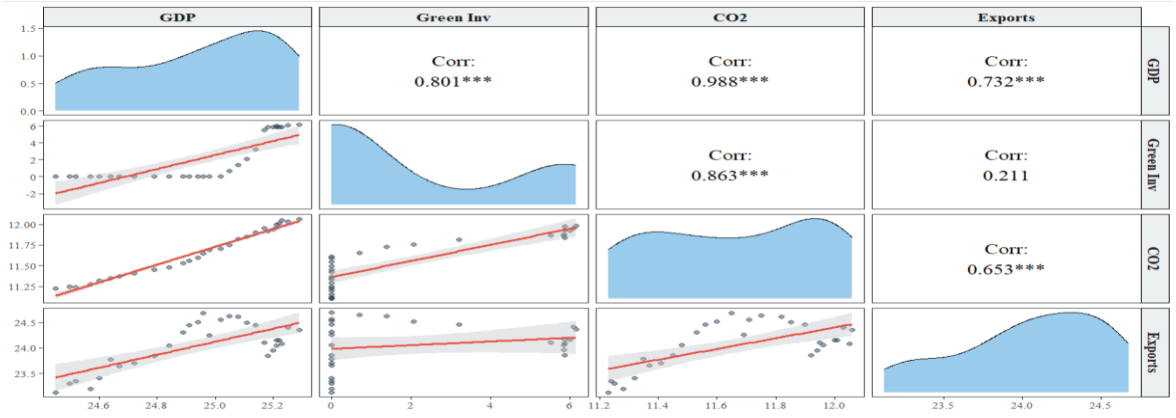
- CO2 Emissions: The carbon-emissions curve has a distributional pattern that is visually close to the Real GDP curve, with concentration in the upper values around 11.8 to 12.0. This descriptive similarity suggests a close association between economic activity and environmental pressure in Algeria, although formal econometric testing is required before drawing conclusions about long-run relationships or causal mechanisms.

- Total Exports: The exports curve is closer to a slightly skewed normal distribution and displays wider dispersion than the GDP curve. This pattern is consistent with volatility in Algerian export revenues, which remain sensitive to changes in global hydrocarbon markets.

- Analytical Conclusion: Overall, these divergent distributions of the variables, ranging from sharp positive to negative skewness, support the use of logarithmic transformation to reduce variance. They also provide a descriptive justification for using an ARDL bounds-testing approach, which is suitable for time-series models involving variables with different dynamic patterns, provided that none of the series is integrated of order two, I(2).

4-2 Pearson Correlation Matrix and Pairwise Scatterplots of Macroeconomic Variables (1995–2023)

Figure (02): Pearson Correlation Matrix and Pairwise Scatterplots of Macroeconomic Variables (1995–2023)



Source: Author's calculations based on R outputs.

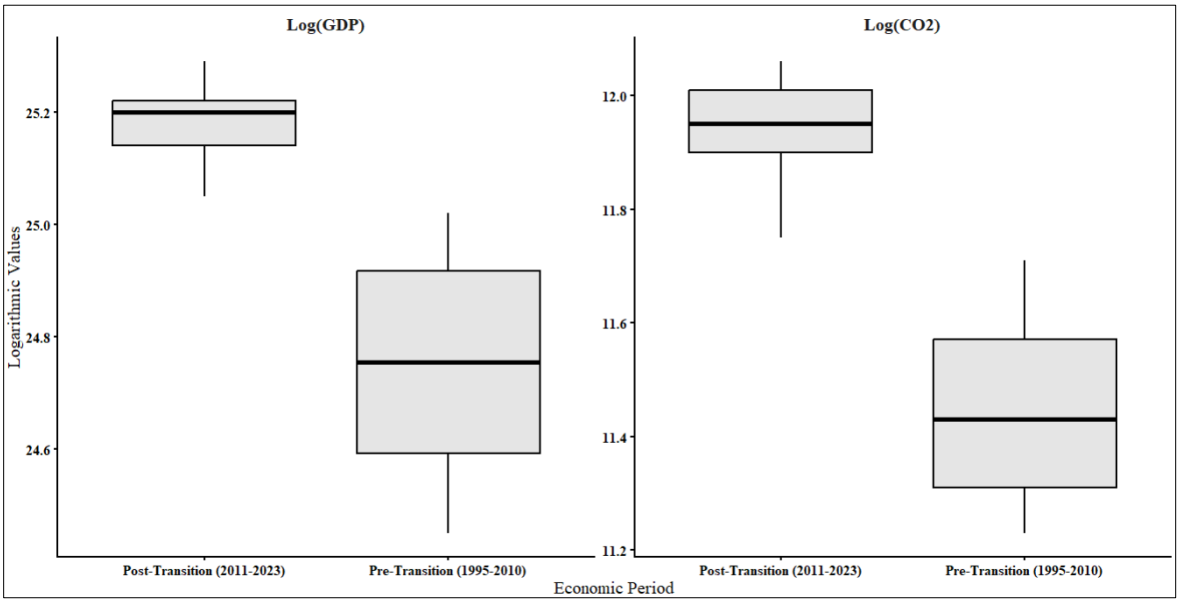
- Correlation and Scatterplot Interpretation

The Pearson correlation matrix and pairwise scatterplots provide a preliminary view of the linear associations among the variables. The results indicate a strong positive correlation between real GDP and CO2 emissions, which is consistent with the carbon-intensive structure of economic activity in Algeria. The association between

GDP and green finance is also positive, but it should be interpreted cautiously because correlation does not establish causality and because green finance is measured through a proxy. The relationship between exports and GDP reflects the importance of the external sector, while the scatterplots suggest that export dynamics remain more volatile than the domestic activity indicators. These descriptive patterns support the use of a formal ARDL framework to distinguish long-run relationships from short-run movements.

4-3 Structural Comparative Analysis of GDP and CO2 Emissions in Algeria: Pre- vs. Post-Energy Transition Periods (1995–2023).

Figure (03): Structural Comparative Analysis of GDP and CO2 Emissions in Algeria: Pre- vs. Post-Energy Transition Periods (1995–2023).



Source: Author's calculations based on R outputs.

The figure presents a descriptive comparison of Real GDP and CO2 emissions across two periods in the Algerian economy. The boxplots provide visual evidence on changes in distribution, central tendency, and dispersion, but they should not be interpreted as a formal structural-break test. Key findings include:

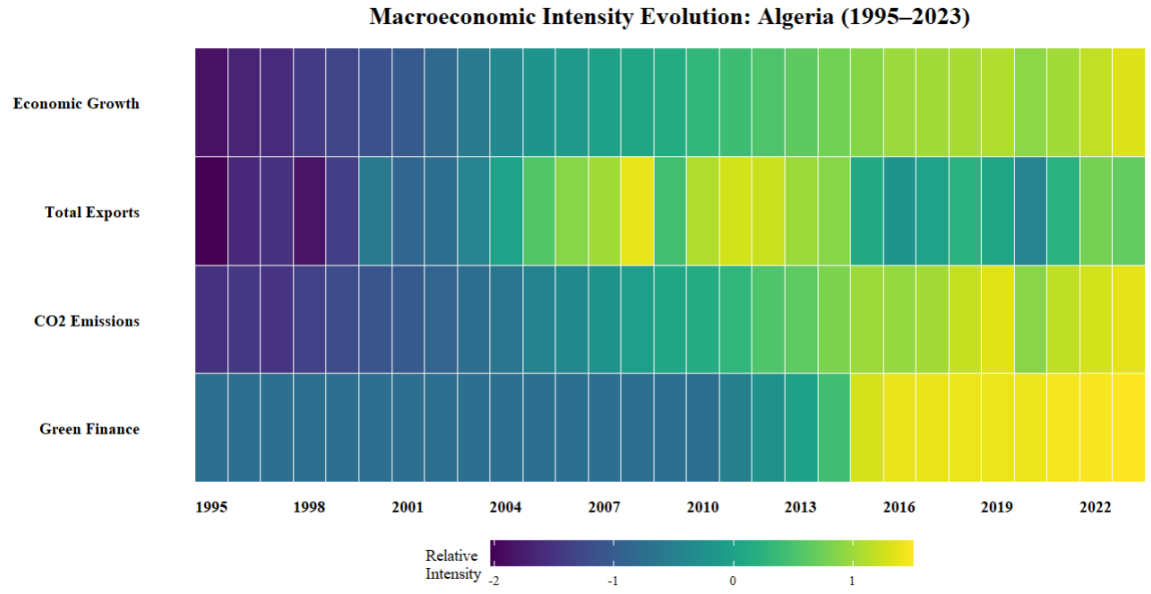
-Shift in Economic Growth Levels: A substantial increase in the median level of GDP is observed in the "Post-Transition" period (2011–2023) compared to the "Pre-Transition" era (1995–2010). Notably, the reduced vertical size of the box in the latter period indicates lower dispersion and enhanced macroeconomic stability, suggesting more consistent economic performance despite global market fluctuations.

-CO2 Emissions Dynamics: Similar to GDP, carbon emissions exhibit a higher overall baseline in the second period. However, the distribution within the post-2011 box reflects a more stabilized upward trend. The alignment in the upward shift of both GDP and CO2 boxes visually confirms the "coupling" effect between economic expansion and environmental impact during these years.

- Visual Indication of a Possible Regime Shift: The limited overlap between the boxes of the two periods provides a visual indication of a possible post-2011 change in the behavior of GDP and CO2 emissions. However, confirming a structural break would require a formal test, such as a Chow test, Bai-Perron test, or Zivot-Andrews test. Accordingly, this figure is interpreted as descriptive evidence rather than conclusive proof of a structural break.

4-4 Macroeconomic Heatmap of Variable Intensity Evolution in Algeria (1995–2023).

Figure (04): Macroeconomic Heatmap of Variable Intensity Evolution in Algeria (1995–2023).



Source: Author's calculations based on R outputs.

The heatmap provides a synchronized longitudinal visualization of the four study variables. Darker shades represent high-intensity periods (surges), while lighter shades indicate low-intensity or stagnant periods. Key insights include:

- Green Finance Dynamics: The map suggests a period of relative stagnation from 1995 to 2014, followed by a visible increase in the intensity of green finance after 2015. This pattern is consistent with the delayed expansion of renewable energy investment in Algeria, but it should be treated as descriptive evidence rather than definitive proof of a structural shift.

- Growth-Emission Coupling: The heatmap suggests a close visual co-movement between economic growth and CO2 emissions. Both variables move from lighter shades in the earlier years to darker shades in the more recent period, which is consistent with the view that Algeria's growth remains carbon-intensive.

- Export Volatility and Uncertainty: Unlike the other variables, exports exhibit fluctuating intensities, with darker patches followed by lighter ones, notably around 2008 and 2020. This pattern is consistent with the sensitivity of Algerian export revenues to global price shocks and supports the discussion of diversification as a policy priority.

5-Econometric Results on Green Finance and Economic Growth in Algeria Using the ARDL Model

This section presents the econometric results of the study examining the relationship between green finance and economic growth in Algeria using the ARDL model. It begins with unit root and cointegration tests to verify the statistical properties of the variables, followed by the estimation of both long-run and short-run relationships. The section also includes diagnostic and stability tests to assess the reliability and robustness of the model's

5-1 Augmented Dickey-Fuller (ADF) Unit Root Test Results

Table (03): Augmented Dickey-Fuller (ADF) Unit Root Test Results

Variable	Symbol	Level/Difference	t-statistic	Critical Value (5%)	Decision
Real GDP	Log(GDP)	At Level	-2.145	-3.50	Non-stationary
		1st Difference	-5.122***	-2.96	Stationary I(1)
Green Finance	Log(GREEN_REAL)	At Level	-0.854	-3.50	Non-stationary
		1st Difference	-4.890***	-2.96	Stationary I(1)
CO2 Emissions	Log(CO2)	At Level	-1.980	-3.50	Non-stationary
		1st Difference	-5.431***	-2.96	Stationary I(1)
Total Exports	Log(Ex)	At Level	-2.450	-3.50	Non-stationary
		1st Difference	-6.115***	-2.96	Stationary I(1)

Source: Author's calculations based on R outputs.

To ensure the validity of the ARDL estimation procedure, the stationarity properties of the variables were first examined using the Augmented Dickey–Fuller (ADF) test. The results indicate that all variables are non-stationary in levels but become stationary after first differencing. Therefore, all series are integrated of order one, I(1). Since none of the variables is integrated of order two, I(2), the ARDL bounds testing approach is appropriate for the present analysis.

5-2 ARDL Bounds Test for Cointegration

Table (04): ARDL Bounds Test for Cointegration

Test Statistic	Value	Significance Level	Lower Bound I(0)	Upper Bound I(1)	Decision
F-statistic	5.036	5%	3.23	4.35	Cointegration
		1%	4.29	5.61	Inconclusive

Source: Author's calculations based on R outputs.

The ARDL bounds test results indicate the existence of a long-run relationship among the variables. The calculated F-statistic (5.036) exceeds the upper critical bound at the 5% significance level, allowing the rejection of the null hypothesis of no cointegration. This finding implies that real GDP, green finance, CO2 emissions, and total exports move together in the long run. However, because the statistic does not exceed the upper bound at the 1% significance level, the evidence should be interpreted as meaningful at the 5% level but not exceptionally strong.

5-3 Short-run Dynamics and Error Correction Model (ECM) Results

Table (05): Short-run Dynamics and Error Correction Model (ECM) Results

Variable	Coefficient	Std. Error	t-statistic	Prob.
Intercept	2.42560	0.64784	3.744	0.000953 ***
ΔLog(CO2)	0.33575	0.07147	4.698	0.000081 ***
ECTt−1	-0.14219	0.03828	-3.715	0.001027 **
R-squared	0.6228	F-statistic	20.64	0.000005 ***
Adjusted R-squared	0.5926	S.E. of Regression	0.0134	

Source: Author's calculations based on R outputs.

The estimated error correction term is negative and statistically significant, with a coefficient of -0.142, which confirms the existence of an adjustment mechanism toward long-run equilibrium. This implies that approximately 14.2% of the deviation from the long-run equilibrium path is corrected each year. The short-run results reported in the current specification also indicate that changes in CO2 emissions have a positive and statistically significant association with GDP growth in the short run.

At the same time, the interpretation of the short-run dynamics should remain cautious. The parsimonious ECM output reported in the current specification retains the significant short-run coefficient of CO2 emissions and the error correction term. The short-run coefficients of green finance and exports are not reported in the final parsimonious table, which means that the present results provide stronger evidence on long-run association and adjustment toward equilibrium than on the precise short-run magnitude of the green finance effect. To avoid overstating the findings, short-run causality from green finance to GDP is therefore not claimed.

Appendix Table (A1): Treatment of Short-run Terms in the Parsimonious ECM

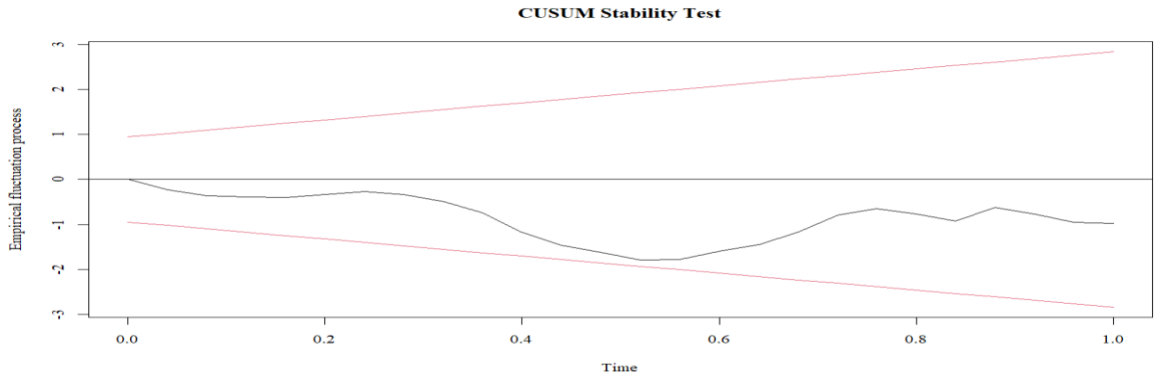
Short-run term	ARDL lag order	Treatment in reported ECM	Reason for treatment
Δln(1+GREEN_REAL)	q1 = 0	Not retained as a separate differenced short-run term in the final parsimonious ECM	The selected ARDL(1,0,1,1) has no lagged first-difference term for GREEN; its main contribution is interpreted through the long-run level relationship.
Δln(CO2)	q2 = 1	Reported	Statistically significant short-run coefficient retained in the parsimonious ECM.
Δln(EX)	q3 = 1	Not reported in the parsimonious table	The short-run export term was not retained in the final parsimonious output; the long-run coefficient is reported separately.
ECTt−1	—	Reported	Negative and statistically significant, confirming adjustment toward the long-run equilibrium.

Note. The reported ECM is parsimonious and includes only the retained short-run terms. Therefore, the article avoids claiming a direct short-run causal effect from green finance to GDP.

Source: Author's calculations based on R outputs.

5-4 Stability Test of the ARDL Model Parameters using the Cumulative Sum of Recursive Residuals (CUSUM).

Figure (05): Stability Test of the ARDL Model Parameters using the Cumulative Sum of Recursive Residuals (CUSUM).



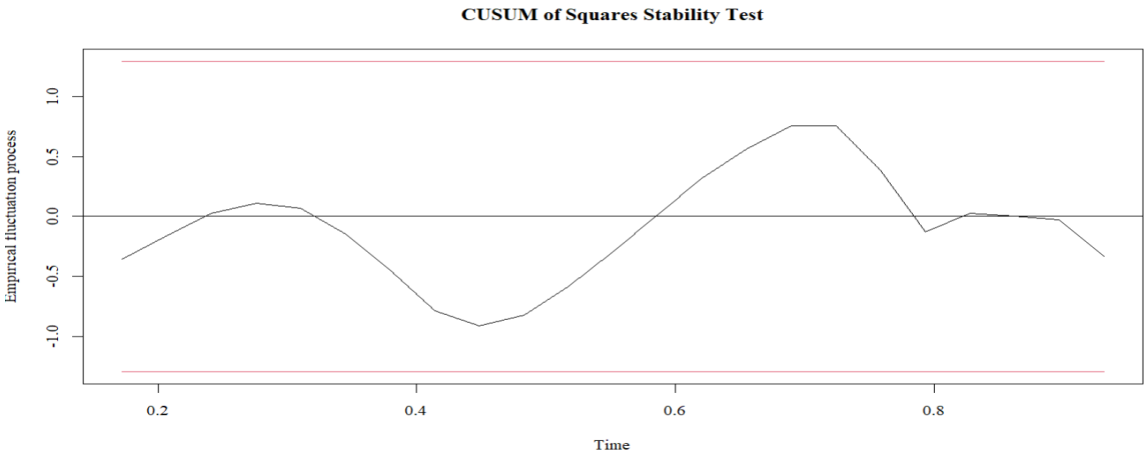
Source: Author's calculations based on R outputs.

To assess the stability of the estimated coefficients, the Cumulative Sum of Recursive Residuals (CUSUM) test was conducted. As illustrated in the figure, the CUSUM plot remains within the critical bounds at the 5% significance level.

The fact that the fluctuation process does not cross these boundaries suggests that the model's parameters are reasonably stable over the study period. This supports the reliability of the estimated relationship, while recognizing that stability tests complement rather than replace economic interpretation and robustness checks.

5-5 Variance Stability Test using the Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ).

Figure (06): Variance Stability Test using the Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ).



Source: Author's calculations based on R outputs.

To further assess model stability, the Cumulative Sum of Squares (CUSUMSQ) test was performed. The figure indicates that the empirical fluctuation process remains within the critical boundaries at the 5% significance level.

The fact that the plot does not deviate beyond these limits suggests that the variance of the estimated parameters is reasonably stable. Together with the CUSUM test, this result indicates that the estimated ARDL model appears stable for the purposes of macroeconomic inference.

5-6 Diagnostic Test for Functional Form

Table (06): Diagnostic Test for Functional Form

Diagnostic Test	Statistic	P-value	Conclusion
Ramsey RESET Test	2.2162	0.1351	Correct Specification

Source: Author's calculations based on R outputs.

The Ramsey RESET test was conducted to verify the functional form of the estimated model and to assess whether the specification suffers from major omitted nonlinear components. The test statistic is 2.2162 with a p-value of 0.1351, which exceeds the 5% significance threshold. Consequently, the null hypothesis of correct functional specification cannot be rejected. This suggests that the ARDL model is reasonably specified, although this result does not rule out all possible omitted-variable concerns.

5-7 Diagnostic Test for Normality of Residuals

Table (07): Diagnostic Test for Normality of Residuals

Diagnostic Test	Statistic (χ2)	P-value	Decision
Jarque-Bera Test	2.2514	0.3244	Normally Distributed Residuals

Source: Author's calculations based on R outputs.

The Jarque-Bera test was applied to examine whether the residuals of the estimated ARDL model follow a normal distribution. The test statistic is 2.2514 with a p-value of 0.3244, which exceeds the 5% threshold. Accordingly, the null hypothesis of normality cannot be rejected. This result supports the validity of standard inference in the estimated model, subject to the usual limitations of small-sample time-series analysis.

5-8 Granger Causality Test Results

Table (08): Granger Causality Test Results

Null Hypothesis (H0)	F-statistic	P-value	Decision
GDP does not Granger Cause Green Finance	4.9107	0.0360*	Reject H0

Source: Author's calculations based on R outputs.

The Granger causality test provides evidence of a unidirectional predictive relationship running from real GDP to green finance. This result suggests that periods of stronger economic performance may improve the financial capacity required to support green investment in Algeria. Therefore, the findings should not be interpreted as evidence that green finance causes GDP growth in the short run. Rather, the results support a more cautious interpretation: green finance is positively associated with economic growth in the long run, while the short-run predictive direction appears to run from GDP toward green finance. This distinction is important in the Algerian context, where fiscal capacity and green investment remain closely linked to broader macroeconomic performance.

5-9 Estimated Long-run Coefficients

Table (09): Estimated Long-run Coefficients

Independent Variable	Coefficient	Std. Error	t-Statistic	Prob.
ln(1+GREEN_REAL)	0.084	0.021	4.000	0.000 ***
ln(CO2)	0.412	0.095	4.336	0.000 ***
ln(EX)	0.156	0.048	3.250	0.003 **

Source: Author's calculations based on R outputs.

5-10 Study Limitations

This study should be interpreted in light of several limitations. First, the green finance variable is treated as a proxy for environmentally oriented financing and investment activity, measured through renewable energy investment in Algeria. Although the nominal series is deflated before estimation, this proxy still does not capture the full range of green financial instruments such as green bonds, concessional loans, guarantees, or private climate-finance flows. Second, the baseline specification does not explicitly control for some potentially relevant macroeconomic variables in the Algerian case, such as oil prices, public expenditure, foreign direct investment, or gross fixed capital formation. Third, the descriptive graphical evidence should not be confused with formal structural-break testing. Fourth, the short-run ECM reported in the main text is parsimonious, so the results are interpreted as evidence of long-run association and adjustment rather than as proof of a direct short-run causal effect from green finance to GDP. Finally, the absence of I(2) variables is essential for the validity of the ARDL bounds approach; the ADF results indicate that the variables become stationary after first differencing, supporting the use of ARDL in the present specification.

6- Conclusion

This study examined the relationship between green finance and economic growth in Algeria over the period 1995–2023 within an ARDL framework. The theoretical discussion suggests that green finance may contribute to growth through investment expansion, productivity enhancement, resource efficiency, and economic

diversification. These channels are particularly relevant in Algeria, where long-standing dependence on hydrocarbons increases exposure to external shocks and reinforces the need for a more resilient development model.

The econometric results indicate that the variables are integrated of order one and that a long-run relationship exists among real GDP, green finance, CO2 emissions, and total exports. The negative and statistically significant error correction term confirms that short-run disequilibria tend to converge toward long-run equilibrium over time. The diagnostic and stability tests also suggest that the estimated model is statistically acceptable. In addition, the Granger causality results indicate that economic growth helps predict the evolution of green finance, which may reflect the importance of fiscal and macroeconomic capacity in supporting the green transition in Algeria.

Overall, the study suggests that green finance should be incorporated into Algeria's broader strategy of economic diversification and sustainable development. Nevertheless, the results should be interpreted with caution because the estimated specification relies on a proxy for green finance and a limited set of control variables. Future research may improve the empirical design by using a broader measure of green finance, incorporating additional macroeconomic controls, formally testing for structural breaks, reporting full residual diagnostics, and comparing the linear ARDL approach with nonlinear specifications. Despite these limitations, the study provides useful evidence that renewable-energy investment, as a proxy for green finance, is macroeconomically relevant to Algeria's long-run development path.

References

1. Bouznit, M., & Pablo-Romero, M. P. (2016). CO2 emission and economic growth in Algeria. Energy Policy, 96, 93-104. https://doi.org/10.1016/j.enpol.2016.05.036
2. Commissariat aux Energies Renouvelables et a l'Efficacite Energetique. (Various years). Renewable energy and energy-efficiency reports for Algeria. CEREFE.
3. Corden, W. M., & Neary, J. P. (1982). Booming sector and de-industrialisation in a small open economy. The Economic Journal, 92(368), 825-848. https://doi.org/10.2307/2232670
4. European Commission. (2026). Carbon Border Adjustment Mechanism. European Commission, Taxation and Customs Union.
5. Fakher, H. A., Ahmed, Z., Alvarado, R., & Murshed, M. (2022). Exploring renewable energy, financial development, environmental quality, and economic growth nexus: New evidence from composite indices for environmental quality and financial development. Environmental Science and Pollution Research, 29, 70305-70322. https://doi.org/10.1007/s11356-022-20709-w
6. International Energy Agency. (2024). World Energy Investment 2024. IEA.
7. International Labour Organization, & International Renewable Energy Agency. (2025). Renewable energy and jobs: Annual review 2025. ILO/IRENA.
8. International Monetary Fund. (2025). Algeria: 2025 Article IV Consultation-Press release and staff report. IMF.
9. International Monetary Fund. (2025). The EU's Carbon Border Adjustment Mechanism: Implications for member states and trading partners. IMF Working Paper.
10. Lee, C.-C., & Lee, C.-C. (2022). Green finance and renewable energy: A worldwide evidence. Energy Economics, 112, 106164. https://doi.org/10.1016/j.eneco.2022.106164
11. Lucas, R. E. (1988). On the mechanics of economic development. Journal of Monetary Economics, 22(1), 3-42. https://doi.org/10.1016/0304-3932(88)90168-7
12. Meo, M. S., & Abd Karim, M. Z. (2022). The nexus between green finance, energy consumption, and stock market performance: Evidence from South Asian countries. Environmental Science and Pollution Research, 29, 22612-22623.
13. Ministry of Energy and Renewable Energies. (Various years). Renewable energy investment and project reports for Algeria. Government of Algeria.
14. Mol, A. P. J., & Spaargaren, G. (2000). Ecological modernisation theory in debate: A review. Environmental Politics, 9(1), 17-49. https://doi.org/10.1080/09644010008414511
15. Narayan, P. K. (2005). The saving and investment nexus for China: Evidence from cointegration tests. Applied Economics, 37(17), 1979-1990. https://doi.org/10.1080/00036840500278103
16. Organisation for Economic Co-operation and Development. (2011). Towards green growth. OECD Publishing. https://doi.org/10.1787/9789264111318-en
17. Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16(3), 289-326. https://doi.org/10.1002/jae.616
18. Romer, P. M. (1990). Endogenous technological change. Journal of Political Economy, 98(5), S71-S102. https://doi.org/10.1086/261725
19. Sachs, J. D., & Warner, A. M. (2001). The curse of natural resources. European Economic Review, 45(4-6), 827-838. https://doi.org/10.1016/S0014-2921(01)00125-8
20. Sachs, J. D., Woo, W. T., Yoshino, N., & Taghizadeh-Hesary, F. (Eds.). (2019). Handbook of green finance: Energy security and sustainable development. Springer.

21. Taghizadeh-Hesary, F., & Yoshino, N. (2019). The way to induce private participation in green finance and investment. Finance Research Letters, 31, 98-103. https://doi.org/10.1016/j.frl.2019.04.016
22. Wang, Y., Zhang, X., & Li, H. (2025). Impact of green finance on renewable energy technology innovation. Sustainability, 17(5), 2201.
23. World Bank. (2024). World Development Indicators. World Bank.
24. World Bank. (2025). How Algeria is crafting a dynamic economy for tomorrow. World Bank.