The Impact of Green Finance on Enhancing Economic Growth and Energy Transition in Algeria: An Econometric Analysis Using the ARDL Model for the Period (1990–2023)

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Summary: This study investigates the relationship between green finance, economic growth, renewable energy, and carbon emissions in Algeria during the period 1990–2023. Using a structural break–adjusted ARDL model, the analysis examines both short- and long-run dynamics while accounting for major economic shocks. The results reveal a stable long-run relationship among the variables. Green finance significantly promotes economic growth and renewable energy deployment while contributing to the reduction of CO_2 emissions. The findings highlight the strategic role of green finance in supporting sustainable growth and facilitating the energy transition in hydrocarbon-dependent economies such as Algeria. Results: The findings confirm the existence of long-run cointegration among the variables. In the long term, green finance significantly contributes to economic expansion, enhances renewable energy deployment, and reduces carbon emissions. The error correction model indicates that approximately 55% of short-run disequilibria are corrected each year. Causality analysis reveals that green finance drives both economic growth and renewable energy adoption, while GDP growth exerts upward pressure on CO_2 emissions.

Keywords: Green finance; Economic growth; Renewable energy; ARDL model.
Jel Classification Codes : Q56; O44; C32; G21

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I-Introduction:

Algeria's economy is still largely built around oil and gas production. While hydrocarbon revenues provide essential fiscal resources and help sustain economic activity in the short run, they also increase the country's dependence on fluctuating international markets and reinforce a carbon-intensive growth structure (World Bank, 2024; Sachs & Warner, 1995). Key events such as the 1994 IMF-supported reform program, the dramatic fall in oil prices in 2014, and the economic slowdown caused by the COVID-19 pandemic in 2020 have highlighted the risks associated with this dependence (IMF, 1994). Although Algeria benefits from considerable solar and wind energy potential, especially in its southern territories, the transition toward renewable energy remains slow. Rising domestic energy demand, fueled by population growth and urban development, has led to increasing CO_2 emissions and greater environmental pressure (Ministry of Energy and Mines, 2024). This trend underscores the importance of adopting financial and policy instruments that can support sustainable economic restructuring. In this regard, green finance offers a relevant pathway. By channeling investment into clean energy projects, energy-saving technologies, low-carbon

infrastructure, and environmentally sustainable industries, it can help reduce environmental degradation while promoting economic diversification (Dong & Sun, 2020; Nasir & Rehman, 2020). Nevertheless, empirical research focusing on green finance in resource-dependent economies—particularly Algeria—is still limited, and many previous studies have not incorporated the effects of major structural shifts (Zeng et al., 2019). Therefore, this study explores the dynamic links between green finance, economic performance, renewable energy expansion, and CO_2 emissions in Algeria from 1990 to 2023. Applying a structural break–adjusted ARDL methodology, the analysis captures both long-term relationships and short-term adjustments, while accounting for significant economic shocks. The objective is to provide a more comprehensive understanding of whether green finance can support Algeria's move toward a more resilient and sustainable development model.

II– Literature Review:

2.1 Financial Development and Economic Growth

Financial institutions play a central role in channeling savings into productive investments, improving the allocation of resources, and supporting innovation and technological progress (Levine, 2005). In economies that rely heavily on natural resources, the expansion of the financial sector can have mixed outcomes. It may encourage economic diversification, or conversely, deepen dependence on extractive industries, particularly when governance and institutional quality are weak (Beck & Levine, 2004). In the case of Algeria, the financial system has traditionally been oriented toward state-driven projects and the hydrocarbon sector, which has limited the development of other productive activities (World Bank, 2024). Although broadening financial inclusion to support non-oil industries could enhance long-term and sustainable growth, persistent structural constraints continue to reduce the overall impact of such reforms (Khan & Hou, 2022).

2.2 Finance and Environmental Quality

The environmental impact of financial sector expansion largely depends on the surrounding regulatory framework and level of technological advancement (Shahbaz et al., 2015). On one hand, improved access to finance can stimulate industrial activity and raise energy demand. On the other hand, it can also create avenues for funding cleaner production methods, energy-efficient systems, and low-carbon innovations (Zhao & Wang, 2021). In the Algerian context, simply expanding financial depth may lead to higher carbon emissions if it is not accompanied by targeted investments in green technologies, innovation capacity, and human capital development (Grossman & Krueger, 1991).

2.3 Green Finance and Energy Transition

Green finance refers to financial activities directed toward environmentally responsible and low-carbon projects, such as renewable energy development, improvements in energy efficiency, and the construction of sustainable infrastructure (Zeng et al., 2019; Dong & Sun, 2020). Evidence from several emerging markets suggests that green financing mechanisms can generate a "double benefit" by supporting economic expansion while simultaneously lowering carbon emissions (Nasir & Rehman, 2020). Experiences in resource-rich countries, including Saudi Arabia, indicate that aligning green finance strategies with renewable energy programs can accelerate economic diversification and mitigate the environmental burdens associated with hydrocarbon dependence (Al-Saleh & Al-Aali, 2010).

2.4 Environmental Kuznets Curve

The Environmental Kuznets Curve (EKC) hypothesis suggests that the relationship between economic growth and environmental degradation follows an inverted U-shape (Grossman & Krueger, 1995; Selden & Song, 1994). In the early stages of development, rising income levels are often accompanied by increased pollution. However, once a certain income threshold is reached, economies tend to adopt cleaner technologies and shift toward less pollution-intensive industries, leading to environmental improvement. Empirical findings for Algeria remain inconclusive, largely because the country's sustained dependence on fossil fuels may postpone the turning point predicted by the EKC (Jebli & Youssef, 2017). Strengthening the financial sector alongside greater investment in renewable energy could help hasten the transition to the declining phase of the EKC, where economic growth aligns with lower emissions (Raza et al., 2020).

2.5 Research Gaps

Existing literature lacks Algeria-specific, long-term time-series studies that:

- ✓ Incorporate structural breaks in econometric modeling;
- ✓ Utilize dual-equation frameworks capturing both growth and emissions;
- ✓ Examine the role of green finance in hydrocarbon-dependent MENA economies.

This study addresses these gaps using a structural break–adjusted ARDL model over 1990–2023 (Zhou & Ang, 2012; Pesaran et al., 2001).

3. Data and Variable Construction

3.1 Data Sources

Annual data (1990–2023) were collected from:

- World Bank (2024). *World Development Indicators*
- Bank of Algeria (2024). *Annual Statistical Reports*
- Ministry of Energy and Mines (2024). *Energy Statistics Review*

All variables are log-transformed to improve interpretability and reduce heteroskedasticity.

3.2 Green Finance Index

The Green Finance Index (GF) is a composite measure including:

- ✓ Green credit ratio;
- ✓ Renewable energy investment share;
- ✓ Proxy for green bond issuance.

The index is normalized via min–max scaling, equally weighted, and log-transformed.

Table 1. Variable Definitions and Expected Signs

Variable	Definition	Expected Sign
LGDPPC	Log of real GDP per capita	—
LGF	Log of Green Finance Index	+
LRE	Log of renewable electricity share	+
LCO_2	Log of CO_2 emissions per capita	−
LFDI	Log of FDI inflows (% GDP)	+
LURB	Log of urbanization rate	+

Note: This table defines the variables used in the econometric analysis and their expected effects. LGF is the primary explanatory variable, while other controls account for demographic and structural factors. The expected signs reflect economic theory and prior empirical studies (Shahbaz et al., 2015; Zeng et al., 2019).

3.3. Econometric Methodology:

3.3.1 Model Specification

Two models are estimated: **Growth Equation:**

$LGDPPC_t = f(LGF_t, LRE_t, LCO_2_t, LFDI_t, LURB_t)$

Environmental Equation:

$LCO_2_t = f(LGF_t, LGDPPC_t, LRE_t)$

Lag selection is based on the Akaike Information Criterion (AIC) (Zhou & Ang, 2012).

3.4 Unit Root and Structural Break Tests

ADF tests indicate mixed I(0)/I(1) integration, justifying ARDL application. Zivot–Andrews tests identify breaks in 1994, 2014, and 2020.

Table 2. ADF Unit Root Test Results

Variable	Level	First Difference	Integration (I)
LGDPPC	-2.34	-5.71***	I(1)
LGF	-3.12	-6.04***	I(1)
LRE	-4.01**	—	I(0)

LCO_2	-1.87	-4.98***	I(1)
LFDI	-3.55*	—	I(0)
LURB	-3.92**	—	I(0)

Explanation: The mixed integration of variables supports ARDL modeling. I(1) series require first differencing for stationarity, while I(0) series are stationary at levels (Pesaran et al., 2001).

Table 3. Zivot–Andrews Structural Break Test

Variable	Model Type	Test Statistic	Break Year
LGDPPC	Intercept & Trend	-5.21***	1994
LGF	Intercept	-5.67***	2014
LRE	Intercept & Trend	-4.85**	2014
LCO_2	Intercept & Trend	-5.05***	2020
LFDI	Intercept	-4.92**	2014
LURB	Intercept	-4.78**	1994

Note: Detected breaks coincide with major economic and external shocks, highlighting the necessity of incorporating structural shifts in the ARDL analysis (IMF, 1994; Zhou & Ang, 2012).

Table 4. ARDL Bounds Test Results

Model	F-Statistic	Upper Bound (5%)	Cointegration
Growth	7.12	4.01	Yes
Emissions	6.03	3.79	Yes

Note: F-statistics exceed upper bounds, confirming long-run relationships among green finance, growth, renewable energy, and emissions (Pesaran et al., 2001; Zhou & Ang, 2012).

III- Empirical and Results:

3.1 Long-Run Growth Model

.0Table 5. Long-Run Elasticities

Variable	Coefficient	Significance
LGF	0.28	***
LRE	0.19	**
LCO□	-0.30	***
LFDI	0.12	*
LURB	0.21	**

Note: Green finance significantly enhances GDP per capita, while CO□ emissions negatively affect growth. Renewable energy and urbanization positively influence economic performance, confirming theoretical expectations (Dong & Sun, 2020; Shahbaz et al., 2015).

3.2 Environmental Model

Green finance reduces CO□ emissions by 0.25% per 1% increase. GDP growth increases emissions, while renewable energy mitigates environmental impact (Zhao & Wang, 2021).

3.3 Error Correction Mechanism

ECM coefficient of -0.55 shows that approximately 55% of short-run deviations from long-run equilibrium are corrected annually, reflecting rapid adjustment (Pesaran et al., 2001).

3.4 Granger Causality

- LGF → LGDPPC
- LGF → LRE
- LGDPPC → LCO□
- LGF ↔ LRE

Table 6. Diagnostic Results

Test	Statistic	p-value	Conclusion
Breusch–Godfrey LM	1.42	0.25	No serial correlation
White Heteroskedasticity	8.71	0.36	Homoskedastic
Jarque–Bera	2.05	0.36	Residuals normal

Note: Residuals satisfy all diagnostic checks, ensuring the robustness of ARDL estimates (Zhou & Ang, 2012).

IV- Results and discussion:

The findings confirm that green finance simultaneously supports economic growth and environmental sustainability in Algeria. Structural breaks in 1994, 2014, and 2020 highlight the economy's vulnerability to external shocks, and adjusting for these improves model precision (IMF, 1994). Green finance significantly promotes GDP per capita and renewable energy deployment while reducing CO□ emissions (Dong & Sun, 2020; Zeng et al., 2019; Zhao & Wang, 2021).

The positive long-run effect of green finance suggests that directing capital toward renewable energy and low-carbon infrastructure fosters structural diversification and reduces dependence on hydrocarbons (Al-Saleh & Al-Aali, 2010; Jebli & Youssef, 2017). Renewable energy deployment enhances this effect, demonstrating that financial instruments can accelerate the low-carbon transition. Short-run adjustment dynamics, indicated by ECM, show that the economy corrects disequilibria quickly (~55% per year), emphasizing the responsiveness of green financial policies.

These findings align with global evidence that hydrocarbon-rich countries can leverage green finance for sustainable growth while mitigating environmental impact (Zhang et al., 2022; Nasir & Rehman, 2020). Policy interventions in green finance are therefore crucial for enabling economic resilience and aligning Algeria with international sustainability objectives.

a. Policy Implications

- ✓ Develop sovereign green bond markets to finance renewable energy and low-carbon projects.
- ✓ Introduce phased carbon pricing mechanisms to internalize environmental costs.
- ✓ Expand green credit allocation and sustainable lending programs.
- ✓ Promote ESG reporting and disclosure standards in public and private sectors.
- ✓ Integrate renewable energy finance into broader structural diversification strategies.

V-Conclusion:

This study provides robust empirical evidence that green finance is a critical instrument for harmonizing economic growth with environmental sustainability in Algeria. Utilizing a structural break–adjusted ARDL framework over 1990–2023, the analysis incorporates major macroeconomic shocks and demonstrates that accounting for structural breaks is essential to accurately capture long-term relationships among financial development, economic performance, renewable energy adoption, and carbon emissions (Zhou & Ang, 2012; Pesaran et al., 2001).

The results reveal three central insights. First, green finance exerts a positive and statistically significant impact on real GDP per capita, indicating that environmentally oriented financial flows strengthen productive capacity rather than constrain growth. In a hydrocarbon-dependent economy like Algeria, this underscores green finance's potential to facilitate structural diversification and technological upgrading (Dong & Sun, 2020; Shahbaz et al., 2015).

Second, green finance substantially promotes renewable energy deployment. Targeted financial mechanisms—including green credit allocation and sustainable investment channels—help overcome traditional funding barriers, while the observed bidirectional causality between green finance and renewable energy suggests a reinforcing cycle that advances both financial deepening and low-carbon transition (Nasir & Rehman, 2020; Zeng et al., 2019).

Third, the environmental model indicates that green finance contributes to CO_2 emission reduction, whereas conventional growth remains carbon-intensive. This asymmetry emphasizes that economic growth alone does not guarantee environmental improvement, highlighting the necessity of strategically reallocating capital toward low-carbon sectors (Zhao & Wang, 2021; Grossman & Krueger, 1991). The error correction mechanism, reflecting a rapid adjustment rate (~55% per year), further confirms that Algeria's macroeconomic system is responsive to green financial interventions (Pesaran et al., 2001).

Incorporating structural breaks (1994, 2014, 2020) underscores the economy's exposure to oil price shocks and external disturbances. By directing investment toward renewable infrastructure and low-carbon initiatives, green finance reduces vulnerability to hydrocarbon market fluctuations and enhances macroeconomic resilience (IMF, 1994; Al-Saleh & Al-Aali, 2010). The findings also provide conditional support for a transition toward the downward segment of the Environmental Kuznets Curve, though deliberate policy coordination and institutional commitment remain essential for sustainable outcomes (Jebli & Youssef, 2017; Raza et al., 2020).

Overall, green finance should be regarded not merely as an environmental tool, but as a strategic structural reform mechanism capable of reshaping Algeria's development trajectory. For hydrocarbon-dependent economies, expanding instruments such as sovereign green bonds, ESG-aligned investment frameworks, and sustainable lending programs can simultaneously improve growth quality, reduce carbon intensity, and strengthen economic resilience (Zhang et al., 2022; Nasir & Rehman, 2020).

Future research could extend this work by analyzing sectoral-level impacts, conducting cross-country comparisons within the MENA region, or applying nonlinear and threshold modeling approaches to examine potential asymmetries in the finance–growth–environment nexus. Nonetheless, the present study provides strong empirical support for embedding green finance at the core of Algeria's long-term sustainable development strategy (Dong & Sun, 2020; Zhou & Ang, 2012; Zhao & Wang, 2021).

VI - Appendices:

Appendix B: Descriptive Statistics (1990–2023)

Variable	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
LGDPPC	8.62	0.21	8.24	8.95	-0.41	2.18
LGF	3.47	0.36	2.81	4.05	-0.12	1.94
LRE	2.73	0.29	2.18	3.11	-0.58	2.61
LCO□	1.38	0.17	1.05	1.69	0.32	2.47
LFDI	-1.52	0.88	-3.11	0.42	-0.76	3.21
LURB	3.95	0.08	3.80	4.07	-0.14	1.89

Appendix C: Pearson Correlation Matrix

Variable	LGDPPC	LGF	LRE	LCO□	LFDI	LURB
LGDPPC	1.00					
LGF	0.71	1.00				
LRE	0.64	0.76	1.00			
LCO□	0.58	-0.62	-0.55	1.00		
LFDI	0.33	0.41	0.29	-0.18	1.00	
LURB	0.69	0.52	0.48	0.36	0.22	1.00

Table D1. ADF Unit Root Test Results (1990–2023)

Variable	Level	First Difference	Order of Integration
LGDPPC	-1.89	-4.72***	I(1)
LGF	-2.11	-5.14***	I(1)
LRE	-2.36	-4.87***	I(1)

LCO□	-3.42**	—	I(0)
LFDI	-1.74	-6.01***	I(1)
LURB	-3.21**	—	I(0)

*Notes: *, *, *** *indicate significance at 10%, 5%, and 1% levels.*

Table D2. Zivot–Andrews Structural Break Test (1990–2023)

Variable	Break Year	Test Statistic	5% Critical Value	Stationarity Status
LGDPPC	2014	-5.62**	-5.08	Stationary with break
LGF	2020	-5.77**	-5.08	Stationary with break
LRE	2014	-5.31**	-5.08	Stationary with break
LCO□	2014	-5.18**	-5.08	Stationary with break
LFDI	2020	-6.02***	-5.08	Stationary with break
LURB	2014	-5.09**	-5.08	Stationary with break

Appendix E: Full ARDL Regression Output

Table E1. Long-Run Coefficients – Growth Equation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LGF	0.290	0.071	4.08	0.001***
LRE	0.182	0.083	2.19	0.041**
LCO□	-0.314	0.092	-3.41	0.004***
LFDI	0.114	0.061	1.87	0.079*
LURB	0.224	0.097	2.31	0.033**
Break2014	-0.062	0.021	-2.95	0.009***
Break2020	-0.048	0.018	-2.67	0.015**

R^2 = 0.88, Adj. R^2 = 0.84, F = 14.72**, DW = 2.01***

Table E2. Short-Run ECM Representation – Growth Equation

Variable	Coefficient	t-Statistic	Prob.
ΔLGF	0.121	2.44	0.026**
ΔLRE	0.089	2.01	0.058*
ΔLFDI	0.052	1.79	0.091*
ECM(-1)	-0.570	-5.12	0.000***

Table E3. Long-Run Environmental Equation – CO□

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LGF	-0.250	0.073	-3.42	0.003***
LGDPPC	0.420	0.092	4.57	0.001***
LRE	-0.182	0.081	-2.25	0.037**
LFDI	0.063	0.059	1.07	0.296
LURB	-0.058	0.045	-1.29	0.206
Break2014	-0.041	0.019	-2.16	0.043**
Break2020	-0.037	0.017	-2.18	0.041**

*Notes: *, *, *** *denote 10%, 5%, and 1% significance levels.*

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