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FINANCIAL DEPTH AND ENVIRONMENTAL SUSTAINABILITY IN ALGERIA: EVIDENCE FROM AN ARDL APPROACH

Lazhari Zouaouid
University of Ghardaia, Faculty of Economic, Commercial and Management Sciences, Laboratory of Applied Studies in Financial and Accounting Sciences, (Algeria)
https://orcid.org/0000-0001-5264-2716

Okba Mekhnane
University of Ghardaia, Faculty of Economic, Commercial and Management Sciences, Laboratory of Applied Studies in Financial and Accounting Sciences, (Algeria)
https://orcid.org/0009-0004-2137-0104

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ABSTRACT

This study examines the relationship between financial depth and environmental sustainability in Algeria over the period 1992–2024 using the Autoregressive Distributed Lag (ARDL) approach. Financial depth is measured by broad money (BM), total bank deposits (DEPT), and domestic credit to the private sector (PRIVATE). At the same time, environmental sustainability is proxied by adjusted savings related to carbon dioxide damage, expressed as a percentage of gross national income (ENV). Annual data were obtained from the Bank of Algeria, the World Bank, and the IMF Financial Access Survey, with environmental observations for 2023–2024 estimated following the World Bank's Adjusted Net Savings methodology. The results provide only borderline evidence of a long-run relationship. None of the financial indicators exerts a statistically significant long-run effect on environmental sustainability. In contrast, broad money and private sector credit have positive and statistically significant short-run effects on environmental damage, while bank deposits remain insignificant. These findings suggest that strengthening the environmental orientation of financial intermediation is more important than expanding financial depth alone to support sustainable development in Algeria.

1 INTRODUCTION

Environmental sustainability has become one of the most pressing policy priorities worldwide as countries seek to reconcile economic development with environmental protection. Rapid industrialization, urban expansion, and increasing energy demand have intensified environmental

Address of the corresponding author:
Lazhari Zouaouid
zouaouid.lazhari@univ-ghardaia.edu.dz

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pressures, particularly in developing economies that rely heavily on fossil fuels. In this context, financial systems are increasingly expected to support the transition toward sustainable development by mobilizing financial resources, promoting green investments, and facilitating the adoption of environmentally friendly technologies. Consequently, understanding whether financial development contributes to environmental sustainability has become an important issue in both academic research and public policy.

Financial depth represents one of the key dimensions of financial development and reflects the capacity of the financial system to mobilize savings, allocate financial resources efficiently, and provide credit to productive sectors. Common indicators of financial depth include broad money, bank deposits, and credit extended to the private sector. A well-developed financial system can improve environmental outcomes by facilitating investment in renewable energy, energy-efficient technologies, and environmentally sustainable infrastructure. However, financial expansion may also stimulate industrial production, energy consumption, and resource exploitation, potentially increasing environmental degradation if financial resources are directed toward pollution-intensive activities. Therefore, the relationship between financial depth and environmental sustainability remains theoretically ambiguous and requires empirical investigation.

Algeria provides an appropriate context for examining this relationship. Although the country has undertaken several initiatives to promote sustainable development and environmental protection, its economy continues to rely heavily on hydrocarbon production and other carbon-intensive activities. At the same time, Algeria's financial sector has experienced gradual structural reforms aimed at improving financial intermediation and expanding access to financial services. Whether these developments have contributed to environmental sustainability remains an open empirical question, particularly given the limited role of green finance within the domestic financial system.

Previous empirical studies have produced mixed findings regarding the environmental implications of financial development. While some studies conclude that financial deepening contributes to environmental improvement by facilitating technological innovation and green investment, others report that financial expansion increases environmental pressures through higher production and energy consumption. Moreover, the direction and magnitude of this relationship vary considerably across countries depending on institutional quality, environmental regulations, and the structure of financial markets. Despite this growing body of literature, empirical evidence for Algeria remains limited, and few studies have simultaneously examined the principal dimensions of financial depth—broad money, bank deposits, and private sector credit—within a unified dynamic framework capable of distinguishing between short-run and long-run effects.

This study seeks to fill this gap by investigating the relationship between financial depth and environmental sustainability in Algeria over the period 1992–2024 using the Autoregressive Distributed Lag (ARDL) approach. The ARDL methodology is particularly suitable because it allows the estimation of both long-run equilibrium relationships and short-run adjustment dynamics when variables are integrated of mixed orders, provided that none is integrated of order two.

The contribution of this study is threefold. First, it provides updated empirical evidence on the relationship between financial depth and environmental sustainability using an extended dataset covering more than three decades of economic developments in Algeria. Second, it jointly examines three complementary indicators of financial depth—broad money, bank deposits, and private sector credit—rather than relying on a single financial indicator. Third, by distinguishing between long-run equilibrium and short-run dynamics through the ARDL framework, the study offers a more comprehensive understanding of how financial deepening interacts with environmental sustainability and provides policy-relevant evidence for promoting sustainable financial development in Algeria.

The remainder of the paper is organized as follows. Section 2 reviews the relevant theoretical and empirical literature. Section 3 presents the data, variables, and research methodology. Section 4 reports and discusses the empirical

findings, while the final section summarizes the main conclusions and policy implications.

2 LITERATURE REVIEW

Financial depth can influence environmental sustainability through competing channels. By mobilizing savings and facilitating investment, financial development may support cleaner technologies, renewable energy, and more efficient production. Conversely, greater liquidity and easier access to credit may stimulate consumption, industrial expansion, and fossil-energy demand, thereby increasing environmental damage. The resulting effect therefore depends on the structure of the financial system, the allocation of finance, the stage of financial development, and the institutional and energy context.

2.1 Financial Development as a Source of Environmental Pressure

Several studies find that financial development increases environmental degradation when financial resources primarily support consumption and carbon-intensive production. Acheampong (2019), using data for 46 Sub-Saharan African countries during 2000–2015, found that broad money, bank credit, and domestic credit to the private sector increased CO_2 emissions. The study also showed that some financial indicators intensified the emissions effect of energy consumption and economic growth.

Using a global sample of 100 countries over 1990–2012, Bui (2020) identified a positive direct effect of financial development on CO_2 emissions. The study attributed part of this effect to higher energy demand and rising living standards generated by financial expansion. Similarly, Shoaib et al. (2020) found a significant positive long-run effect of financial development on emissions in both the G8 and D8 groups, although its magnitude was more pronounced in the developing-country group.

Evidence from emerging economies supports this adverse channel. Khan et al. (2022) reported that overall financial development, together with its depth, access, and efficiency dimensions, reduced environmental quality in 15 emerging and growth-leading economies during 1984–2018. Habiba and Xinbang (2022) also found that the development of financial institutions and financial markets contributed to CO_2 emissions in 46 Sub-Saharan African countries, although renewable energy consumption reduced emissions and moderated some of these effects.

For Pakistan, Shahbaz et al. (2016) found that bank-based financial development contributed to environmental degradation, indicating that financial resources were not sufficiently directed toward environmentally friendly activities. Ahmed et al. (2020) further demonstrated that the relationship can be asymmetric: positive and negative changes in financial development did not have identical effects on environmental degradation and environmental sustainability.

2.2 Financial Development as Support for Environmental Improvement

Other studies indicate that finance can improve environmental outcomes when it facilitates technological innovation, financial stability, and cleaner investment. Nasreen et al. (2017), examining South Asian economies over 1980–2012, found that financial stability reduced CO_2 emissions in the long run, whereas economic growth, energy consumption, and population density worsened environmental quality.

Shahbaz et al. (2018) found that financial development reduced carbon emissions in France during 1955–2016, while energy research innovation also improved environmental quality. By contrast, foreign direct investment and energy consumption increased emissions. Abbasi and Riaz (2016) reached a more qualified conclusion for Pakistan: financial variables contributed to emission mitigation mainly during the more financially liberalized subperiod of 1988–2011, but their mitigating effect remained smaller than the emissions-increasing effect of per capita income.

Acheampong et al. (2020) showed that the environmental consequences of financial markets depend on the stage of financial development. Financial market development, depth, and efficiency reduced carbon-emission intensity in developed and emerging financial economies but increased it in frontier economies and had no direct effect in standalone financial economies. More recent evidence from 18 emerging economies indicates that financial-market depth and efficiency, as well as the development and

accessibility of financial institutions, can reduce greenhouse-gas emissions, although financial development does not uniformly promote all renewable-energy sources (Parashar & Jaiswal, 2025).

2.3 Mixed, Nonlinear, and Context-Dependent Evidence

A substantial part of the literature rejects a uniform relationship between finance and the environment. Li et al. (2015), using 102 countries over 1980–2010, found mutually reinforcing interactions among financial development, environmental quality, and economic growth. Their analysis also identified nonlinear relationships involving financial development and growth, as well as economic growth and carbon emissions.

Ruza and Caro-Carretero (2022) found nonlinear relationships between financial development and several environmental indicators in the G7 countries. Financial development displayed a U-shaped association with CO_2 and total greenhouse-gas emissions, an inverted-U relationship with methane emissions, and a positive association with adjusted net savings, while its relationship with the ecological footprint was statistically insignificant. These findings show that conclusions may change according to the environmental indicator employed.

Fakher et al. (2022), using composite measures for financial development and environmental quality, found that the interactions among finance, renewable energy, environmental quality, trade, and economic growth differed between high- and low-income countries. Their results underline the importance of national income levels and the use of multidimensional indicators when assessing finance–environment relationships.

Regional evidence is similarly mixed. Omri et al. (2015), examining 12 MENA countries during 1990–2011, found neutrality between financial development and CO_2 emissions, while identifying bidirectional causality between emissions and economic growth and unidirectional causality from financial development to growth. In contrast, Qaysi (2025) found that financial-market access and depth increased CO_2 emissions in 17 MENA countries, whereas financial-market efficiency reduced them.

2.4 Literature Synthesis and Research Gap

The reviewed evidence confirms that the environmental effect of financial development is neither consistently favorable nor uniformly adverse. It varies according to the financial indicator, the stage and structure of the financial system, the destination of credit, the energy mix, institutional conditions, and the environmental measure adopted. In particular, broad money and private credit can increase environmental pressure when they stimulate energy-intensive consumption and production, but financial depth may improve environmental performance when resources are directed toward cleaner technologies and sustainable investment.

Despite the growing international evidence, country-specific research on Algeria remains limited. Previous studies have generally examined broad international or regional panels, relied on composite financial-development indices, or used CO_2 emissions in physical units as the environmental variable. Consequently, insufficient attention has been given to the separate effects of monetary liquidity, deposit mobilization, and private-sector credit on the economic cost of carbon damage in Algeria.

The present study addresses this gap by examining broad money, total bank deposits, and domestic credit to the private sector within a unified ARDL model for the period 1992–2024. Environmental sustainability is represented by carbon dioxide damage as a percentage of gross national income; therefore, an increase in ENV indicates greater environmental damage, whereas a decrease denotes an improvement in environmental sustainability. The distinction between short-run dynamics and long-run coefficients also makes it possible to determine whether the environmental effects of financial depth are temporary or persistent.

3 METHODOLOGY

3.1 Data Collection Sources

The study uses annual data for Algeria covering 1992–2024. Financial-depth indicators were

compiled from the Bank of Algeria, the World Bank, and the IMF Financial Access Survey. Environmental sustainability is represented by adjusted savings: carbon dioxide damage as a percentage of gross national income (ENV). World Bank observations were used through 2022. The environmental values for 2023–2024 were estimated by the authors following the World Bank's Adjusted Net Savings methodology using carbon dioxide emissions data from the Global Carbon Project and Gross National Income (GNI) data from the World Bank national accounts database.

Table 1. *Data Sources and Definition of the Study Variables*

Variable	Code	Measurement	Role	Source
Environmental sustainability	ENV	Adjusted savings: CO_2 damage (% of GNI)	Dependent	World Bank (1992–2022); authors' calculations (2023–2024) based on the World Bank Adjusted Net Savings methodology using Global Carbon Project CO_2 emissions data and World Bank GNI data.
Broad money	BM	Broad money (% of GDP)	Independent	Bank of Algeria
Bank deposits	DEPT	Total bank deposits (% of GDP)	Independent	Bank of Algeria; IMF Financial Access Survey for recent observations
Private-sector credit	PRIVATE	Domestic credit for the private sector (% of GDP)	Independent	Bank of Algeria; World Bank

Source: Prepared by the authors.

3.2 Statistical Methodology

The empirical analysis applies the Autoregressive Distributed Lag (ARDL) bounds-testing approach developed by Pesaran, Shin, and Smith (2001). The method is appropriate for a small annual sample and permits regressors integrated at I(0) and I(1), provided that no variable is I(2). It also estimates short-run dynamics and long-run coefficients within a unified framework. The updated dataset contains 33 annual observations, although the selected ARDL specification uses 31 effective observations after accounting for lags.

The analysis proceeds through descriptive statistics, Augmented Dickey–Fuller unit-root tests, selection of the optimal lag structure by the Akaike Information Criterion, the ARDL bounds test, estimation of the long-run equation and error-correction model, and residual diagnostic and stability tests. The final specification selected from the updated results is ARDL(1,2,0,1).

3.3 Scope of the Study (Spatial, Temporal, and Analytical)

3.3.1 Spatial Scope

The analysis is confined to Algeria, where financial reforms since the early 1990s have expanded the role of banks and monetary intermediation. This setting provides an appropriate case for assessing whether greater financial depth has translated into improved environmental sustainability.

3.3.2 Temporal Scope

The study covers 1992–2024, yielding 33 annual observations and capturing the post-reform evolution of Algeria's financial system and environmental costs.

3.3.3 Analytical Scope

Financial depth is measured by BM, DEPT, and PRIVATE, while ENV measures carbon-related damage as a percentage of GNI. Since a higher ENV value denotes greater environmental damage, a positive coefficient indicates environmental deterioration, whereas a negative coefficient indicates improvement.

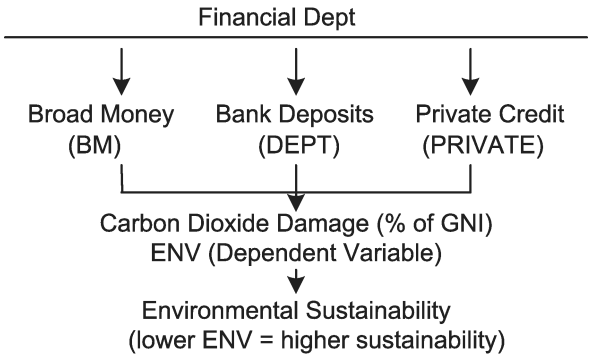

Figure 1. *Conceptual Model of the Study*
Source: Prepared by the authors

3.4 Study Model

The study addresses the following research question: To what extent does financial depth affect environmental sustainability in Algeria over 1992–2024? The corresponding hypothesis states that financial-depth indicators exert statistically significant short- and/or long-run effects on ENV.

3.5 Model Specification and Variable Measurement

3.5.1 Model Specification

After the functional relationship is expressed as:

$$ENV_t = f(BM_t, DEPT_t, PRIVATE_t)$$

the selected ARDL(1,2,0,1) specification includes one lag of ENV, two lags of BM, no lag of DEPT, and one lag of PRIVATE. The associated error-correction representation is used to identify the immediate effects of changes in financial depth and the speed at which ENV returns to equilibrium after a short-run disturbance.

3.5.2 Data Management and Measurement

The annual series were organized for EViews estimation. The database contains 33 complete observations for each variable; lagged estimation reduces the effective ARDL sample to 31 observations. The measures used in the model are summarized below.

Table 2. Summary of Variables and Measurement

Variable group	Indicator	Code	Scale
Environmental sustainability	Adjusted savings: CO_2 damage (% of GNI)	ENV	Quantitative (%)
Financial Depth	Broad money (% of GDP)	BM	Quantitative (%)
	Total bank deposits (% of GDP)	DEPT	Quantitative (%)
	Domestic credit to the private sector (% of GDP)	PRIVATE	Quantitative (%)

Source: Prepared by the authors

- **Dependent variable**

ENV captures the monetary damage associated with carbon dioxide emissions relative to GNI. Because it is a damage indicator, higher values reflect weaker environmental performance.

- **Independent variables**

BM reflects economy-wide liquidity; DEPT captures the banking system's capacity to mobilize savings; and PRIVATE represents bank financing supplied to the private sector. Their environmental effects depend on how financial resources are allocated between carbon-intensive and environmentally sustainable activities.

3.6 Descriptive Variables

Descriptive statistics provide an initial overview of the characteristics and distribution of the study variables over the period 1992–2024. Table 3 reports the mean, median, minimum, maximum, standard deviation, skewness, kurtosis, and Jarque–Bera statistics.

Table 3. Descriptive Statistics of the Study Variables

Statistics	PRIVATE	DEPT	BM	ENV
Mean	14.3121	41.5739	65.4000	2.9101
Median	13.1000	43.4000	64.4000	2.7668
Maximum	29.2000	53.7000	95.6000	4.9102
Minimum	3.9000	21.8000	35.6000	1.7044
Std. Dev.	7.1090	8.4846	14.9910	0.8776
Skewness	0.3507	–0.9423	–0.1050	0.7427
Kurtosis	2.0402	2.9778	2.3506	2.6637
Jarque-Bera	1.9431	4.8841	0.6405	3.1895
Probability	0.3785	0.0870	0.7260	0.2030

Source: Authors' calculations based on EViews 10 outputs.

The descriptive statistics indicate moderate variability across all variables during the study period. Broad money (BM) records the highest average (65.40% of GDP), followed by bank deposits (41.57% of GDP) and private sector credit (14.31% of GDP), while the environmental

sustainability indicator (ENV) averages 2.91% of GNI. The Jarque–Bera probabilities exceed the 5% significance level for all variables, suggesting that their distributions do not significantly depart from normality. These characteristics indicate that the data are suitable for subsequent econometric analysis.

3.7 Stationarity Test and Optimal Lag Selection

3.7.1 Stationarity Test

Before estimating the ARDL model, the order of integration of each variable was examined using the Augmented Dickey–Fuller (ADF) unit root test. The ARDL approach requires that none of the variables be integrated of order two (I(2)), while allowing a combination of I(0) and I(1) variables. The ADF results reveal a mixture of integration orders across the variables. Broad money (BM) is stationary at level under the specification including a constant and trend, whereas ENV, DEPT, and PRIVATE become stationary after first differencing. Since none of the variables is integrated of order two, the stationarity requirement for applying the ARDL bounds testing approach is satisfied. The coexistence of I(0) and I(1) variables therefore justifies the use of the ARDL framework to investigate both the short-run and long-run relationships among the study variables.

Table 4. *Augmented Dickey–Fuller Unit Root Test Results*

Variables	Level			First Difference		
	Const & Trend	Constant	None	Const & Trend	Constant	None
PRIVATE	(-2.443) 0.3519	(-0.953) 0.7576	(0.534) 0.8260	(-4.304) **0.0095**	(-4.336) **0.0018**	(-4.256) **0.0001**
DEPT	(-2.989) 0.1511	(-2.087) 0.2507	(0.308) 0.7689	(-5.985) **0.0002**	(-5.860) **0.0000**	(-5.804) **0.0000**
BM	(-4.398) **0.0076**	(-1.437) 0.5518	(0.370) 0.7856	(-5.003) **0.0017**	(-5.089) **0.0002**	(-5.124) **0.0000**
ENV	(-1.337) 0.8599	(-1.089) 0.7075	(0.632) 0.8479	(-4.059) **0.0169**	(-4.134) **0.0031**	(-4.130) **0.0002**

Source: Authors' calculations based on EViews 10 outputs.

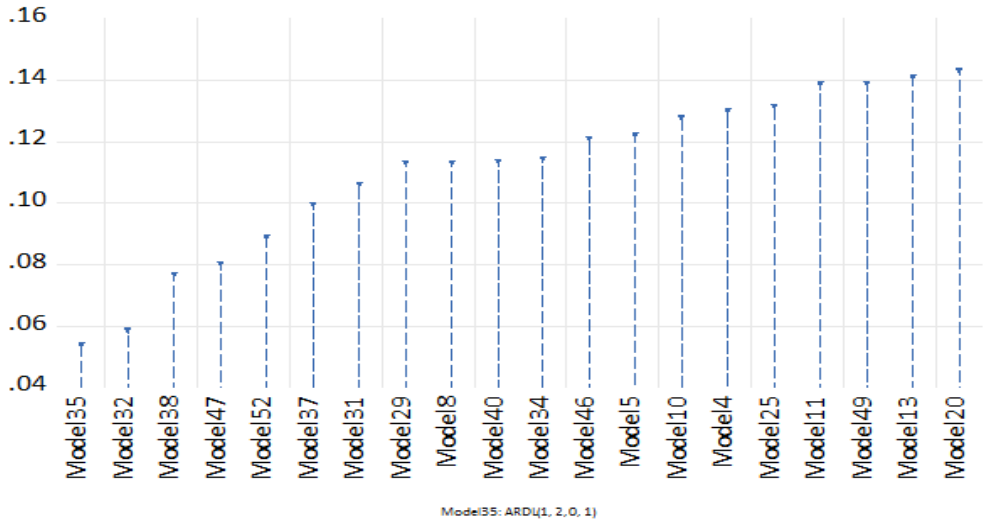

Figure 2. *Akaike Information Criterion (AIC) for the Top ARDL Models*
Source: Authors' calculations based on EViews 10 outputs.

3.7.2 Optimal Lag Length Selection

Selecting the optimal lag structure is a prerequisite for estimating the ARDL model, as it ensures an appropriate balance between model fit and parsimony. The lag order was determined using the Akaike Information Criterion (AIC), which evaluates alternative model specifications and selects the one with the lowest information criterion.

Figure 2 presents the Akaike Information Criterion (AIC) for the best-performing ARDL specifications estimated in this study. The results indicate that

the ARDL(1,2,0,1) model achieves the minimum AIC value among the competing specifications and was therefore selected as the optimal model for the subsequent cointegration and error-correction analyses. The selected specification provides the best trade-off between goodness of fit and model simplicity, thereby reducing the risks of over-parameterization while preserving the explanatory power of the estimated model.

4 RESULTS AND DISCUSSION

4.1 ARDL Model Estimation

Following the preliminary diagnostic procedures, the Autoregressive Distributed Lag (ARDL) approach was employed to examine the relationship between financial depth and environmental sustainability in Algeria. Based on the Akaike Information Criterion (AIC), the ARDL(1,2,0,1) specification was selected as the optimal model. This specification was subsequently used to investigate both the long-run equilibrium relationship and the short-run adjustment dynamics among the study variables.

The estimated unrestricted error correction representation of the ARDL model is expressed as follows:

$$\Delta \mathbf{ENV}_t = \delta_0 + \sum_{i=1}^{p} \delta_{1i}\, \Delta \mathrm{ENV}_{t-1} + \sum_{i=0}^{q1} \delta_{2i}\, \Delta \mathrm{PRIVATE}_{t-i} + \sum_{i=0}^{q2} \delta_{3i}\, \Delta \mathrm{DEPT}_{t-i} + \sum_{i=0}^{q3} \delta_{4i}\, \Delta \mathrm{BM}_{t-i} + \theta_1 \mathrm{ENV}_{t-1} + \theta_2 \mathrm{PRIVATE}_{t-1} + \theta_3 \mathrm{DEPT}_{t-1} + \theta_4 \mathrm{BM}_{t-1} + \varepsilon_{3t} \quad (1)$$

Where:

- Δ denotes the first differences of the variables, representing short-term effects.
- q1, q2, and q3 refer to the number of lags for the independent and dependent variables, determined based on information criteria such as AIC or SBC.
- δ_0 is the intercept term in the model.
- ε_{3t} is the stochastic error term.
- θ_i represents the long-run coefficients between the variables.

4.1.1 Cointegration Testing Using the Bounds Test (F-Bounds Test)

The existence of a long-run relationship among the variables was examined using the ARDL bounds testing procedure proposed by Pesaran et al. (2001). The test compares the calculated F-statistic with the lower and upper critical bounds to determine whether the variables are cointegrated.

Table 5. Results of the ARDL Bounds Test

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	**3.182034**	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66
Actual Sample Size	31		Finite Sample: n=35	
		10%	2.618	3.532
		5%	3.164	4.194
		1%	4.428	5.816
			Finite Sample: n=30	
		10%	2.676	3.586
		5%	3.272	4.306
		1%	4.614	5.966

Source: Authors' calculations based on EViews 10 outputs.

Based on the results reported in Table 5, the calculated F-statistic equals 3.182, with an effective sample size of 31 observations. This value exceeds the lower critical bound at the 5%

significance level but remains below the corresponding upper bound for finite samples. Accordingly, the bounds test provides borderline evidence regarding the existence of a long-run equilibrium relationship.

Nevertheless, the subsequent estimation of the error correction model reveals a negative and highly significant error correction coefficient, indicating that deviations from the long-run equilibrium are corrected over time. Taken together, these findings support proceeding with the estimation of both the long-run coefficients and the short-run dynamics within the ARDL framework.

4.1.2 Long-Run Estimation

The long-run relationship between financial depth and environmental sustainability was estimated using the selected ARDL(1,2,0,1) specification. The estimated long-run coefficients are reported in Table 6.

Table 6. *Long-Run Levels Equation*

Levels Equation Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
BM	0.440935	0.647549	0.680929	0.5027
DEPT	-1.006181	1.277446	-0.787651	0.4389
PRIVATE	0.265611	0.496945	0.534489	0.5981
C	12.20006	14.09650	0.865468	0.3957
EC = CO2 - (0.4409*BM -1.0062*DEPT + 0.2656*PRIVATE + 12.2001				

Source: Authors' calculations based on EViews 10 outputs.

The long-run estimates indicate that none of the financial depth indicators exerts a statistically significant effect on environmental sustainability over the study period. Specifically, broad money (BM) displays a positive coefficient (0.441), while bank deposits (DEPT) exhibit a negative coefficient (−1.006). Private sector credit (PRIVATE) also records a positive coefficient (0.266). However, the probability values associated with all three variables exceed the conventional 5% significance level, suggesting that these long-run effects are statistically insignificant.

These findings imply that financial deepening alone has not been sufficient to generate lasting improvements in environmental sustainability in Algeria. The absence of significant long-run effects may reflect the limited integration of environmental objectives into financial intermediation, as well as the continued dominance of carbon-intensive economic activities during the study period. Consequently, the long-run relationship between financial depth and environmental sustainability appears to be weak from a statistical perspective.

Table 7. *Error Correction Model (ECM)*

ECM Regression Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(BM)	0.026580	0.010315	2.576861	0.0169
D(BM(-1))	0.017331	0.005967	2.904290	0.0080
D(PRIVATE)	0.139190	0.025810	5.392946	0.0000
CointEq(-1)*	**-0.053599**	0.012402	-4.321707	**0.0003**
R-squared	0.683014	Mean dependent var		0.056992
Adjusted R-squared	0.647793	S.D. dependent var		0.346725
S.E. of regression	0.205771	Akaike info criterion		-0.204190
Sum squared resid	1.143227	Schwarz criterion		-0.019160
Log likelihood	7.164951	Hannan-Quinn criter.		-0.143875
Durbin-Watson stat	2.498961			

* p-value incompatible with t-Bounds distribution.

Source: Author's calculations based on EViews 10 outputs

4.1.3 Short-Run Dynamics and Error Correction Model

The Error Correction Term (ECM or CointEq(-1)) is the most crucial outcome at this stage, as it reflects the speed at which the short-run dynamics adjust to restore the long-run equilibrium. This is illustrated in Table 7.

The estimated error correction coefficient CointEq(−1) is −0.0536 and statistically significant at the 1% level (p = 0.0003), confirming the existence of a stable long-run adjustment mechanism. The negative sign satisfies the theoretical expectation, indicating that approximately 5.4% of short-run disequilibrium is corrected each year, implying a gradual convergence toward the long-run equilibrium following temporary shocks.

Regarding the short-run coefficients, changes in broad money exert a positive and statistically significant effect on the environmental indicator in both the current and the previous period. Likewise, changes in private sector credit have a positive and highly significant short-run effect. These findings suggest that short-term expansions in liquidity and private credit are associated with increases in the environmental indicator during the adjustment process. In contrast, bank deposits do not exhibit a statistically significant short-run effect.

Overall, the empirical evidence indicates that the relationship between financial depth and environmental sustainability is primarily driven by short-run dynamics rather than statistically significant long-run effects. While the estimated long-run coefficients remain insignificant, the significant error correction mechanism confirms that temporary deviations from equilibrium are gradually corrected over time, supporting the dynamic specification of the ARDL model.

4.2 Diagnostic Tests (Model Adequacy Tests)

The validity of the results is confirmed through a set of diagnostic tests, including model adequacy, normality test, autocorrelation test of the model residuals, heteroskedasticity test of the residual series, in addition to tests for the stability of model parameters. The results indicate that the estimated model meets the following requirements:

- There is no autocorrelation in the residuals, as the p-value for the relevant test exceeds 0.05.
- The residual variance is homoskedastic, with a p-value for the heteroskedasticity test also exceeding 0.05.
- The CUSUM and CUSUM of Squares plots lie within the critical bounds, indicating parameter stability throughout the entire sample.

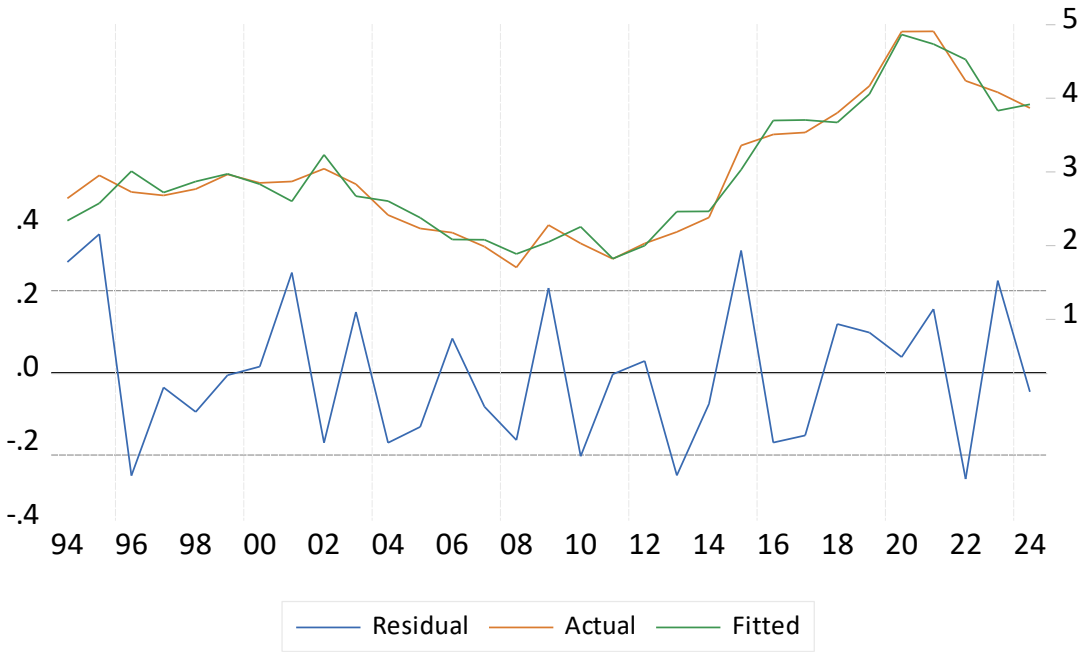

Figure 3. *Model Adequacy*

Source: EViews 10 Outputs

4.2.1 Model Adequacy

To assess the model's adequacy, actual values are compared with the estimated values, as illustrated in Figure 3.

The figure clearly shows that the estimated values closely align with the actual values, reflecting the accuracy of the estimated model and its adequacy in representation. Therefore, the model can be reliably used for interpreting and analyzing the results.

4.2.2 Normality Test

A normality test was conducted to verify the consistency of the data with the fundamental assumption of the analysis.

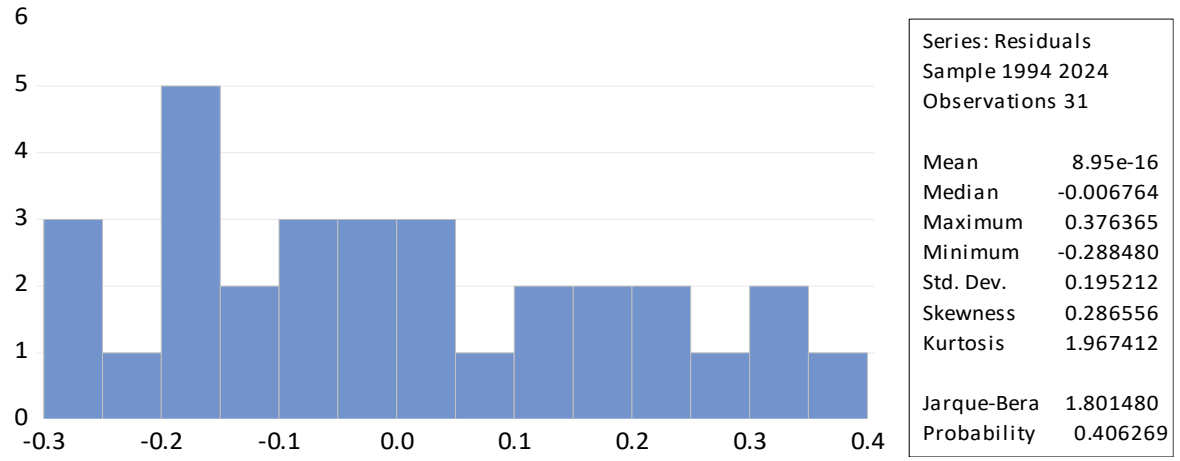

Figure 4. *Normality Test*

Source: EViews 10 Outputs

The results of the Jarque-Bera normality test indicate that the model residuals follow a normal distribution. The test's p-value was 0.4062, which is significantly greater than the 5% significance level. This suggests there is insufficient evidence to reject the null hypothesis of normality, and thus, this serves as a positive indicator of the statistical suitability of the model.

4.2.3 Serial Correlation Test of the Model Residuals

To verify the independence of the residuals and ensure that autocorrelation does not compromise the validity of the model's results, a serial correlation test of the residuals was conducted.

Table 8. *Breusch-Godfrey Serial Correlation LM Test Results*

Breusch-Godfrey Serial Correlation LM Test:			
Null hypothesis: **No serial correlation at up to 2 lags**			
F-statistic	2.535376	Prob. F(2,21)	0.1032
Obs*R-squared	6.029489	Prob. Chi-Square(2)	0.5491

Source: Author's calculations based on EViews 10 outputs

The results of the Breusch-Godfrey test for detecting serial correlation in the model's residuals show that both the p-value of the F-statistic (0.1032) and that of the Chi-Square statistic (0.5491) exceed the conventional significance level of 0.05. Therefore, there is insufficient statistical evidence to reject the null hypothesis of no autocorrelation, indicating that the model's residuals are free from serial correlation. This is a positive indicator that reinforces the efficiency and reliability of the model estimates, eliminating the need for model respecification or further adjustments.

4.2.4 Heteroskedasticity Test of the Residual Series

To check for the presence of heteroskedasticity in the error terms, the ARCH test was conducted as follows.

Table 9. ARCH Heteroskedasticity Test Results

Heteroskedasticity Test: ARCH			
F-statistic	1.801888	Prob. F(1,28)	0.1903
Obs*R-squared	1.813867	Prob. Chi-Square(1)	0.1780

Source: Author's calculations based on EViews 10 outputs

The results of the ARCH test for heteroskedasticity in the model's residuals show that the p-values for both the F-statistic (0.1903) and the weighted R-squared statistic (0.1780) are higher than the standard 0.05 significance level. This suggests that there is insufficient evidence to reject the null hypothesis of homoskedasticity. Accordingly, it can be concluded that the residuals do not suffer from heteroskedasticity, which further supports the reliability of the model results and the accuracy of the estimations without the need for corrective statistical procedures.

4.2.5 CUSUM and CUSUM of Squares Tests

To ensure the stability of the model's parameters over time, both the CUSUM and CUSUM of Squares tests were conducted. The results are shown below:

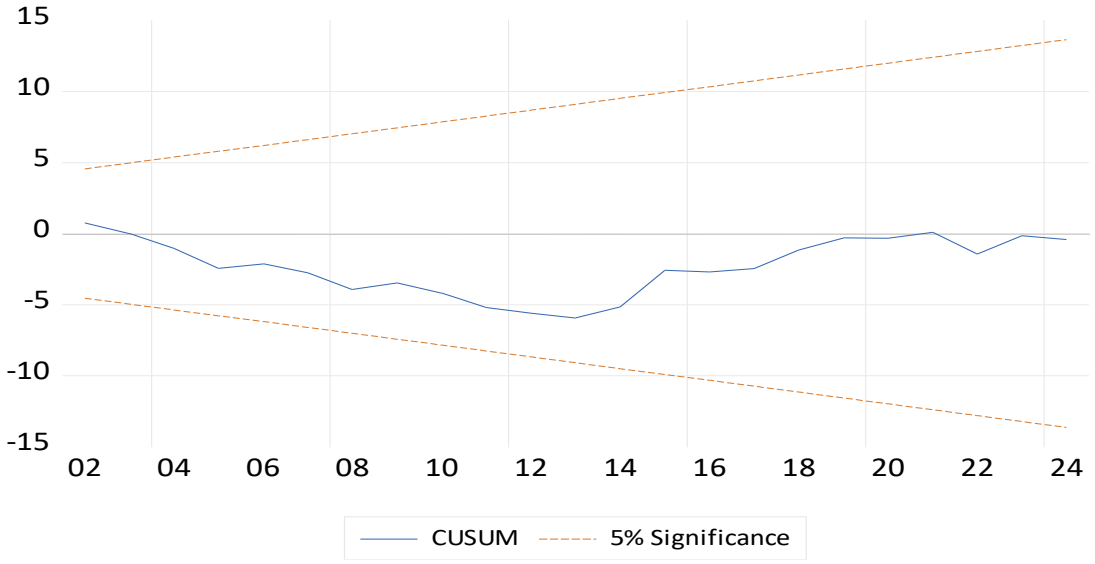

Figure 5. CUSUM Test Results

Source: EViews 10 Outputs

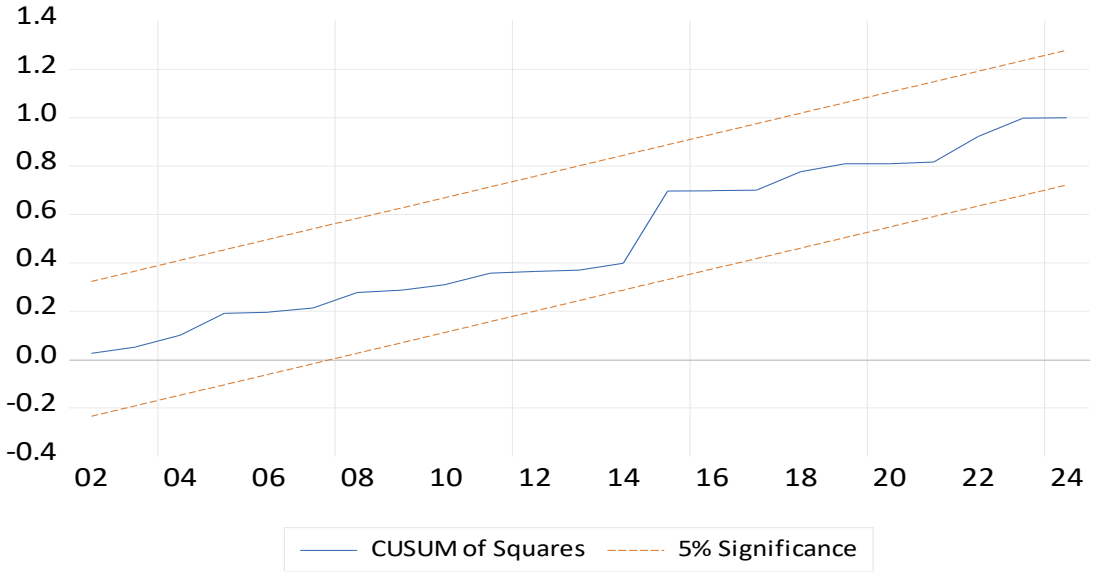

Figure 6. CUSUM of Squares Test Results

Source: EViews 10 Outputs

The CUSUM and CUSUM of Squares (CUSUMSQ) tests confirm the structural stability of the estimated ARDL model over the period 1992–2024, as both statistics remain within the 5% critical bounds throughout the sample period. These findings indicate that the estimated coefficients are stable and that no structural instability is detected. This evidence is further supported by the diagnostic tests, including the Breusch–Godfrey serial correlation test and the ARCH heteroskedasticity test, all of which confirm the adequacy and reliability of the estimated model. Consequently, the empirical results can be considered robust for interpreting the relationship between financial depth and environmental sustainability in Algeria.

4.3 Discussion of Results (Economic Analysis)

The empirical findings reveal that the relationship between financial depth and the environmental damage indicator (ENV) is driven mainly by short-run dynamics rather than statistically established long-run effects. Although the bounds-test statistic provides only borderline evidence of cointegration, the negative and statistically significant error-correction coefficient indicates the presence of an adjustment mechanism through which deviations from the long-run path are gradually corrected. The estimated adjustment rate of approximately 5.4% per year is relatively slow, suggesting that environmental damage responds only gradually to changes in financial conditions.

In the long run, broad money exhibits a positive coefficient, whereas bank deposits have a negative coefficient and private-sector credit has a positive coefficient. However, none of these estimates is statistically significant. The absence of significant long-run coefficients indicates that the expansion of monetary liquidity, deposit mobilization, and private credit has not produced a stable and identifiable effect on carbon-dioxide damage in Algeria. This result may reflect the limited capacity of the financial system to influence the economy's structural and technological composition. Algeria's bank-based financial system primarily performs conventional intermediation functions, while green credit, sustainable investment instruments, and environmental criteria in financing decisions remain insufficiently developed. Consequently, changes in financial depth alone may be unable to generate persistent improvements or deterioration in environmental sustainability.

The insignificant positive long-run coefficient of broad money suggests that greater monetary liquidity does not necessarily translate into a permanent increase in environmental damage. Nevertheless, its positive sign is consistent with the possibility that monetary expansion may support consumption, production, and energy demand without systematically directing resources toward cleaner technologies. The lack of statistical significance distinguishes the Algerian case from the results reported by Acheampong (2019), Bui (2020), and Shoaib et al. (2020), who found that financial development or broad financial expansion increased carbon emissions in their respective samples. It is closer to the neutrality result reported by Omri et al. (2015) for the direct relationship between financial development and CO_2 emissions in MENA countries.

Bank deposits carry a negative but statistically insignificant long-run coefficient. The negative sign could imply that stronger deposit mobilization has the potential to reduce environmental damage when savings are transformed into productive and environmentally efficient investment. However, the insignificant result indicates that this channel is not sufficiently strong in Algeria. Deposits may increase the resources available to banks without guaranteeing their allocation to renewable energy, cleaner production, or low-carbon infrastructure. This finding therefore differs from evidence that financial stability or well-developed finance improves environmental quality, as reported by Nasreen et al. (2017) and Shahbaz et al. (2018), but it does not contradict those studies because the present analysis measures deposit depth rather than financial stability or the overall quality of financial development.

The positive but insignificant long-run coefficient of private-sector credit similarly suggests that credit expansion has not generated a persistent environmental effect. Its positive direction may reflect the concentration of credit in conventional commercial, construction, transport, and energy-related activities rather than explicitly green sectors. Yet the lack of significance means that private credit cannot be considered a statistically

reliable long-run determinant of environmental damage. This differs from the emissions-increasing effects of private credit documented by Acheampong (2019) and the broader adverse effects reported by Khan et al. (2022). The difference may be attributed to Algeria's relatively limited financial depth, the restricted role of private investment, and the dominance of public and hydrocarbon-related activity in the economy.

The short-run results are more pronounced. Changes in broad money, including its lagged change, exert positive and statistically significant effects on ENV. Because a higher value of ENV represents greater carbon-dioxide damage as a percentage of gross national income, these coefficients imply that short-term monetary expansion increases environmental pressure. A plausible explanation is that liquidity growth initially stimulates aggregate demand, consumption, imports, transport activity, and production before cleaner technologies or efficiency improvements can offset the associated environmental costs. This result is consistent with the scale and energy-demand channels emphasized by Bui (2020) and with the adverse environmental effects of broad money identified by Acheampong (2019).

Private-sector credit also has a positive and significant short-run effect on environmental damage. This suggests that additional credit may initially finance activities associated with higher fossil-energy consumption and carbon-intensive production. The result is consistent with the argument that financial expansion can worsen environmental performance when lending is not guided by environmental standards. Similar adverse effects have been reported by Shahbaz et al. (2016), Habiba and Xinbang (2022), and Khan et al. (2022). In Algeria, the result may also reflect the limited development of green lending frameworks and the absence of strong incentives encouraging banks to differentiate between environmentally sustainable and pollution-intensive projects.

By contrast, changes in bank deposits do not have a significant short-run effect. Deposit accumulation therefore appears insufficient, by itself, to alter environmental damage. This can be explained by the distinction between resource mobilization and resource allocation: a rise in deposits expands banks' potential funding base, but its environmental consequences depend on whether those funds are converted into credit, the sectors receiving that credit, and the technologies financed.

Taken together, the results suggest that financial depth in Algeria generates temporary environmental pressures without producing statistically significant long-run effects. This pattern is economically plausible in a financial system where liquidity and credit can stimulate short-term economic activity but are not yet systematically integrated into a green-finance strategy. The findings also support the broader literature showing that the environmental consequences of finance are context-dependent. Acheampong et al. (2020) demonstrated that the impact of financial markets differs across stages of financial development, while Qaysi (2025) found that financial depth and access increased emissions in the MENA region but financial efficiency reduced them. Thus, increasing the size of the financial system is not sufficient to reduce environmental damage or improve environmental sustainability; the efficiency, composition, and environmental orientation of financial intermediation are equally important.

From a policy perspective, the positive short-run effects of broad money and private credit indicate that Algeria should complement financial deepening with mechanisms that influence the destination of financial resources. These may include green-credit guidelines, environmental risk assessment in bank lending, preferential finance for renewable energy and energy efficiency, and improved disclosure of the environmental impact of financed projects. The objective should not be to restrict financial development, but to transform it from a predominantly quantitative expansion of liquidity and credit into a more selective and environmentally aligned process of resource allocation.

5 CONCLUSION

This study examined the relationship between financial depth and environmental sustainability in Algeria over the period 1992–2024 using the Autoregressive Distributed Lag (ARDL) approach. Financial depth was represented by broad money, total bank deposits, and domestic credit to the

private sector, while environmental sustainability was measured by carbon dioxide damage as a percentage of gross national income.

The empirical findings indicate that financial depth does not exert statistically significant long-run effects on environmental sustainability. However, broad money and private sector credit display positive and statistically significant short-run effects on environmental damage, while the error-correction mechanism confirms a gradual adjustment toward long-run equilibrium. These results suggest that financial expansion in Algeria has generated mainly temporary environmental pressures rather than persistent long-run environmental effects.

This study contributes to the literature by providing updated evidence for Algeria using an extended dataset covering 1992–2024 and by jointly examining three complementary dimensions of financial depth within a unified ARDL framework. Unlike many previous studies relying on aggregate indicators of financial development, the present research distinguishes the respective roles of monetary liquidity, bank deposits, and private-sector credit in explaining environmental sustainability.

From a policy perspective, the findings indicate that expanding financial depth alone is unlikely to improve environmental sustainability. Greater emphasis should therefore be placed on directing financial resources toward environmentally sustainable investment through green credit policies, environmental risk assessment in bank lending, and stronger support for renewable energy and energy-efficiency projects.

Study Limitations. This study has several limitations. It focuses exclusively on Algeria, relies on annual macroeconomic data, and measures environmental sustainability using a single proxy based on carbon dioxide damage as a percentage of gross national income. Although the dataset was extended to 2024, the sample remains relatively small because of the annual frequency of the data.

Future research may extend the analysis by incorporating additional indicators of financial development, financial inclusion, green finance, and institutional quality, while employing alternative environmental indicators and nonlinear or asymmetric econometric models to provide a broader understanding of the finance–environment nexus.

REFERENCES

Abbasi, F., & Riaz, K. (2016). CO_2 emissions and financial development in an emerging economy: An augmented VAR approach. *Energy Policy, 90*, 102–114. https://doi.org/10.1016/j.enpol.2015.12.017

Acheampong, A. O. (2019). Modelling for insight: Does financial development improve environmental quality? *Energy Economics, 83*, 156–179. https://doi.org/10.1016/j.eneco.2019.06.025

Acheampong, A. O., Amponsah, M., & Boateng, E. (2020). Does financial development mitigate carbon emissions? Evidence from heterogeneous financial economies. *Energy Economics, 88*, 104768. https://doi.org/10.1016/j.eneco.2020.104768

Ahmed, F., Kousar, S., Pervaiz, A., & Ramos-Requena, J. P. (2020). Financial development, institutional quality, and environmental degradation nexus: New evidence from asymmetric ARDL cointegration approach. *Sustainability, 12*(18), 7812. https://doi.org/10.3390/su12187812

Bui, D. T. (2020). Transmission channels between financial development and CO_2 emissions: A global perspective. *Heliyon, 6*(11), e05509. https://doi.org/10.1016/j.heliyon.2020.e05509

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

Habiba, U., & Xinbang, C. (2022). An investigation of the dynamic relationships between financial development, renewable energy use, and CO_2 emissions. *SAGE Open*, *12*(4), 1–21. https://doi.org/10.1177/21582440221134794

Khan, M. A., Khan, M. A, Ahmed, M., & Khan, K. (2022). Environmental consequences of financial development in emerging and growth-leading economies: A multidimensional assessment. *Borsa Istanbul Review, 22*(4), 668–677. https://doi.org/10.1016/j.bir.2021.10.003

Li, S., Zhang, J., & Ma, Y. (2015). Financial development, environmental quality and economic growth. *Sustainability*, *7*(7), 9395–9416. https://doi.org/10.3390/su7079395

Nasreen, S., Anwar, S., & Ozturk, I. (2017). Financial stability, energy consumption and environmental quality: Evidence from South Asian economies. *Renewable and Sustainable Energy Reviews, 67*, 1105–1122. https://doi.org/10.1016/j.rser.2016.09.021

Omri, A., Daly, S., Rault, C., & Chaibi, A. (2015). Financial development, environmental quality, trade and economic growth: What causes what in MENA countries. *Energy Economics, 48*, 242–252. https://doi.org/10.1016/j.eneco.2015.01.008

Parashar, M., & Jaiswal, R. (2025). Financial access, depth, and efficiency: The key pillars for enhancing energy equity, security, and sustainability. *Environmental Challenges, 19*, 101117. https://doi.org/10.1016/j.envc.2025.101117

Qaysi, T. (2025). Financial market depth, access, and efficiency and environment nexus in MENA region: Cross-sectional dependence analysis. *Sustainability, 17*(5), 2160. https://doi.org/10.3390/su17052160

Ruza, C., & Caro-Carretero, R. (2022). The non-linear impact of financial development on environmental quality and sustainability: Evidence from G7 countries. *International Journal of Environmental Research and Public Health, 19*(14), 8382. https://doi.org/10.3390/ijerph19148382

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

Shahbaz, M., Shahzad, S. J. H., Ahmad, N., & Alam, S. (2016). Financial development and environmental quality: The way forward. *Energy Policy, 98*, 353–364. https://doi.org/10.1016/j.enpol.2016.09.002

Shoaib, H. M., Rafique, M. Z., Nadeem, A. M., & Huang, S. (2020). Impact of financial development on CO_2 emissions: A comparative analysis of developing countries (D8) and developed countries (G8). *Environmental Science and Pollution Research, 27*(11), 12461–12475. https://doi.org/10.1007/s11356-019-06680-z