

Financial inclusion and sustainable development in Algeria: an empirical analysis using the ARDL Model (2004-2022)

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Abstract. *In a global context marked by climate urgency and the requirements of the Sustainable Development Goals (SDGs), financial inclusion emerges as a strategic lever for equitable, green, and resilient growth. This study aims to empirically evaluate the impact of financial inclusion on sustainable development in Algeria, employing an ARDL model applied to annual data covering the period 2004-2022 due to data availability constraints. The analysis relies on four main variables: money supply (M2), private sector credit, bank deposit, and digital infrastructure measured by the number of ATMs.*

The results reveal differentiated effects in the short and long term: while digital access and bank credit stimulate sustainable development in the short term, only money supply (M2) exhibits a significant positive long-term effect, while other variables remain insignificant or unstable over time. These findings suggest the necessity of an inclusive strategy combining financial education, service digitalization, and green finance. The study also highlights structural limitations and methodological constraints specific to the Algerian context, while calling for a reform of public policies regarding inclusive finance.

Keywords: financial inclusion, sustainable development, ARDL model, Algeria, financial education.

JEL Classification: G21, G28, O11, Q01.

1. Introduction

Since the adoption of the 2030 Agenda by the United Nations, sustainable development has become a global imperative structuring economic, social, and environmental policies. In this dynamic, financial inclusion is now recognized as a fundamental lever for achieving several Sustainable Development Goals (SDGs), particularly those related to poverty reduction (SDG 1), equal opportunities (SDG 5), sustainable growth (SDG 8), and inequality reduction (SDG 10) (Demirgüç-Kunt et al., 2022). Financial inclusion refers to equitable access and effective use of formal financial services—savings, credit, insurance, payment methods—by all social categories.

The determinants of financial inclusion are now well identified in the literature: banking infrastructure density (ATMs, branches), credit access, bancarization level, service digitalization, financial regulation quality, and financial education. These factors interact with the structural characteristics of national economies to shape the trajectory of growth and sustainable development (Demirgüç-Kunt et al., 2022).

Recent empirical literature has highlighted the positive effects of financial inclusion on human development, productivity, economic resilience, and even ecological transition (Levine, 2005; World Bank, 2022). Studies such as those by Elfaki & Ahmed (2024) in Asia or Afful et al. (2025) in West Africa have used ARDL models to quantify the dynamic relationships between financial inclusion and macroeconomic indicators. Similarly, Huo et al. (2024) demonstrated that the inclusion-fintech combination significantly reduces ecological footprint in emerging countries.

However, the majority of existing studies focus on Asian countries, Anglophone African countries, or emerging countries with high banking density. The case of Algeria remains little explored, despite specific challenges related to its dependence on hydrocarbons, limited financial infrastructure outside major cities, the extent of the informal sector, and still embryonic digitalization.

Nevertheless, some recent Algerian works allow us to nuance this observation. Khellil (2024) proposes an advanced reading of development in Algeria by valorizing local community structures, particularly mosques, as vectors of financial inclusion and social entrepreneurship. He draws on community finance models experimented in Malaysia and mobilizes the reflections of Malek Bennabi and Ibn Khaldoun to articulate spirituality, endogenous development, and economic justice. This approach offers an alternative perspective on resource mobilization in a low banking density environment.

Richa and Touil (2024), for their part, emphasize the role of digital technologies in sustainable governance of natural resources, particularly water. Their study, focused on the agricultural sector, highlights the importance of sustainability-oriented digitalization, suggesting that digital management tools must be integrated into sustainable agricultural financing policies.

At the regional scale, Raimi et al. (2025) include Algeria in a comparative analysis of African countries. Their results reveal that financial inclusion, when associated with a controlled trade opening policy, contributes significantly to sustainable growth.

Finally, Mansour (2024) explores the integration of artificial intelligence in Algerian banking systems. He defends the necessity of proactive regulation for these technological innovations to truly contribute to inclusion and sustainability, by reducing asymmetries in financing access.

The literature review shows an important shortage of empirical work applied to the Algerian context, both methodologically and analytically. Few studies mobilize an econometric framework capable of modeling the short and long-term effects of financial variables on the development trajectory. The complexity of the Algerian financial system, its institutional evolution, and its low depth justify a specific and contextualized analysis.

In this perspective, the present study aims to evaluate the impact of financial inclusion on sustainable development in Algeria, over the period 2004–2022. The analysis relies on an ARDL (Autoregressive Distributed Lag) model, allowing distinction between short-term and long-term dynamics, while taking into account the heterogeneity of time series integration levels.

This study contributes to the existing literature in several ways. First, it provides one of the few empirical analyses focusing on the relationship between financial inclusion and sustainable development in Algeria over the period 2004–2022. Second, it applies the ARDL model to distinguish between short- and long-term effects, offering a dynamic perspective often overlooked in previous studies. Third, the study integrates multiple dimensions of financial inclusion, including monetary, banking, and digital indicators, providing a more comprehensive framework. Finally, it offers policy-relevant insights for improving financial inclusion strategies in a country characterized by structural and institutional specificities.

The study mobilizes four key variables of financial inclusion: money supply (M2), private sector credit, bank deposit volume, and digital banking infrastructure (measured by the number of ATMs-automated teller machines-per 100,000 adults). Sustainable development is measured by GDP per capita at constant prices, in coherence with the literature.

The approach follows a hypothetico-deductive logic, based on the economic mechanisms described above. Hypotheses are formulated to be econometrically tested via the ARDL model.

Hypothesis

H1: Financial inclusion has a positive and statistically significant effect on sustainable development in Algeria in the short and long run.

Specific Hypotheses

H1a - Money supply (M2/GDP): An increase in money supply relative to GDP has a positive effect on sustainable development, due to the expansion of economic liquidity and support for long-term investments.

H1b - Private sector credit (% GDP): The increase in bank credit to the private sector contributes positively to sustainable development, via financing of productive activities and entrepreneurial projects.

H1c - Deposit volume (% GDP): Increased savings mobilization, measured by bank deposit volume, favors sustainable economic growth through endogenous investment financing.

H1d - Digital access to banking services (ATM/100k adults): Higher density of digital banking infrastructure (ATM) improves financial inclusion and, consequently, stimulates sustainable development through better service accessibility.

Null hypothesis

HO: There is no economically or statistically significant relationship between financial inclusion indicators and sustainable development in Algeria.

This analytical and hypothetical framework is based both on existing literature and on the structural specificities of the Algerian economy. By mobilizing an ARDL model, the study intends to provide concrete response elements to political decision-makers and financial institutions engaged in reforms related to inclusive finance and the country's economic transition.

2. Literature Review

At the heart of 21st-century economic transformations, financial inclusion has become a political and academic priority. The need to provide everyone with equitable access to safe, affordable, and innovative financial services is seen as a catalyst for sustainable development. While the Sustainable Development Goals (SDGs) call for inclusive, green, and digital growth, several researchers have turned to the ARDL (Autoregressive Distributed Lag) model to model the complex dynamics between financial inclusion and sustainability indicators. This review proposes an analytical journey through recent studies published in high-level scientific journals (Elsevier, Wiley, Springer), offering a comparative and enriched perspective.

2.1. Inclusion, Fintech, and Green Sustainability

In a study covering seven Asian countries, Elfaki & Ahmed (2024) test the technological Kuznets curve hypothesis via PMG/ARDL. They demonstrate that equitable access to financial services reduces social inequalities (SDG 10) and stimulates savings and sustainable investments. In China, Zhao and Zhao (2024) show how digital finance, via mobile payments and online loans, supports technological democratization in the renewable energy sector, thus reducing territorial inequalities.

Similarly, Fang et al. (2024) observe that energy innovation, combined with financial digitalization, improves sustainable growth indicators in a green transition context. This dynamic is also confirmed by Dong et al. (2024), who demonstrate that financial inclusion

reduces energy inequalities in China, through accelerated access to low-carbon technologies.

At the sub-Saharan Africa scale, Akono & Kemezang (2024) highlight the synergy between FinTech and energy transition in reducing income inequalities. Complementarily, Ahiase et al. (2024) analyze the moderating role of income inequalities in the impact of digital financial inclusion on environmental sustainability in Africa.

In the ASEAN context, Wong et al. (2023) reveal that financial innovation reinforces the redistributive effect of inclusion on poverty and income inequalities. Finally, through a qualitative study in the United Kingdom, Smith et al. (2023) show that inclusive innovation in local smart energy systems can mitigate energy injustices, provided digital divides are overcome.

2.2. Fintech and Inclusion

The rise of fintech and digital finance plays a crucial role in economic inclusion and inequality reduction. For example, Akono & Kemezang (2024) show that fintech, coupled with energy transition, has ambivalent effects on income inequalities in sub-Saharan Africa. Their econometric approach emphasizes the importance of structuring financial innovation policies around social justice. Zhao & Zhao (2024) examine the relationship between digital finance and inequalities in renewable energy technology innovation. They conclude that financial digitalization can exacerbate inequalities if not accompanied by targeted policies.

Cen & Yin (2024) highlight the role of fintech and green finance as vectors of participatory and low-carbon development in several Asian countries. Through ARDL, they identify lasting effects on environmental quality. Similarly, Huo et al. (2024) use NARDL to demonstrate that in the extended G7 (E7) countries, financial inclusion coupled with fintech innovations significantly reduces ecological footprint.

These observations fit into a broader dynamic confirmed by Dai et al. (2025), who show that fintech and green finance support low-carbon energy policies in BRICS countries. Similarly, Guermazi (2025) identifies digital and inclusive finance adoption as levers of sustainable growth, social inclusion, and carbon footprint reduction, particularly through massive adoption in rural areas.

Finally, Koemtzopoulos & Zournatzidou (2025) explore the trajectory of cryptocurrencies toward carbon neutrality, highlighting the role of eco-efficient policies and green technologies in the transition of fintechs toward "greentech" models.

2.3. Inclusion, Innovation, and Energy Transition

Tekin et al. (2024) explore the impact of green investments, via ARDL, on energy performance in OECD countries. They establish that sustainable finance is more efficient when it relies on an inclusive base. In the same line, Işık et al. (2025) show how artificial intelligence, combined with ESG principles (governance, environment, social) and inclusive finance, catalyzes energy transition in advanced economies.

Dai, Zhang & Hussain (2025) propose "policy pathways" linking fintech and green finance to accelerate energy transition in BRICS countries. They identify policy levers that can facilitate a shift toward low-carbon energy sources.

Complementarily, Cen & Yin (2024) explore the synergy between fintech, green finance, and digitalization in improving environmental quality. They emphasize that digital integration enables not only more efficient management of green investments, but also better transparency and traceability.

These results echo the work of Dunbar et al. (2024), who emphasize fintech's promises for environmental sustainability, while warning against digital inequalities that can hamper its inclusive potential. Gopal & Pitts (2025) propose an analytical framework to integrate AI, data science, and ESG into sustainable finance strategies, emphasizing technology's fundamental role in contemporary energy governance. Additionally, Bonfanti (2023) analyzes ESG innovations in the fintech industry, proposing instruments like carbon credits and ethical algorithms to guide the ecological transition of financial systems.

2.4. Financial Inclusion for Decent Work and Economic Growth

Financial inclusion plays a central role in sustainable economic development strategies, particularly for developing countries facing structural challenges in access to finance, employment, and training. Within the framework of SDG 8, which promotes sustainable growth and decent work, it represents a transversal lever enabling support for entrepreneurship, encouraging investment, and strengthening the participation of vulnerable populations in the formal economy.

Several recent research studies confirm this dynamic. A study by Rafsanjani et al. (2025) highlights the growing impact of digital financial services in emerging economies. By relying on trend analysis in various countries of the Global South, the authors show how financial technologies have facilitated economic integration of segments long excluded from the traditional banking system.

In the renewable energy sector, Abdirahman, Asif and Mohsen (2025) demonstrate that access to circular and inclusive financing enables local ecosystem dynamization and anchors development in more resilient and autonomous economic models. This link between inclusion and green transition opens concrete perspectives for economies such as Algeria, engaged in structural reforms.

Finally, Ray et al. (2025) emphasize the success conditions of inclusion; beyond technical tools, real impact depends on institutions' capacity to remove educational barriers particularly financial and green education regulatory and technological barriers. Their analysis recalls that inclusive finance diffusion must imperatively be accompanied by a long-term financial education strategy, to avoid disguised exclusion effects. In this perspective, financial inclusion cannot be reduced to simple transaction formalization; it must be conceived as a vector of economic empowerment, professional path securitization, and as a tool for sustainable social cohesion.

2.5. Inclusion Against Informality and Poverty

Afful et al. (2025) demonstrate, through the ARDL model, that expanding financial inclusion enables informal economy formalization in Ghana. This formalization strengthens fiscal capacities and improves public policy efficiency. Similarly, Dada et al. (2022) reveal that financial inclusion contributes to reducing ecological footprint in Africa by tackling the informal economy, whose activities often escape environmental regulations.

In the Ghanaian context, Afful, Bentum-Ennin & Bondzie (2025) analyze how financial development influences the informal economy using the ARDL model. They demonstrate a bidirectional relationship between the two, suggesting that inclusive financial policies can favor economy formalization while stimulating growth.

In South Asia, Shawon et al. (2025) reveal the essential role of social entrepreneurship, supported by inclusive financial instruments, in reducing structural poverty. A dynamic confirmed by Azam Khan & Nawab (2024), who show that inclusive financial innovations associated with renewable energies mitigate the effects of urban poverty and environmental degradation.

Essel-Gaisey & Chiang (2022) emphasize that in Ghana's context, access to formal financial services favors environmental resilience of poor and marginalized households, particularly in informal urban areas.

2.6. Green Inclusion: Finance, Energy, and Biodiversity

Tang (2024) illustrates that in economies affected by corruption, financial inclusion plays a moderating role in reducing biodiversity loss through better regulation of extractive investments, as also confirmed by Li & Qamruzzaman (2023), who emphasize that financial inclusion reduces dependence on fossil fuels while favoring ecologically responsible behaviors.

In the Chinese context, Fang et al. (2024) demonstrate that green energy innovation, supported by digitalization, contributes to reshaping sustainable and inclusive growth. Their study insists on the necessity of an innovative ecosystem combining digital policies and environmental incentives.

Moreover, Ali (2025) explores how formal financial services, particularly those accessible in marginalized areas, can limit deforestation and improve natural resource management. This is supported by Warikandwa et al. (2023), who show that in Namibia, financial inclusion plays a strategic role in climate adaptation, particularly by reducing dependence on fossil fuels in subsistence practices.

Finally, in OECD countries, Tekin, Dirir & Aden (2024) analyze how green investments influence energy performance. Their study highlights a positive link between sustainable finance policies and energy intensity reduction, advocating for better integration between climate and financial policies.

2.7. Inclusion as a Vector for Renewable Investment

Zhang & Guo (2024) demonstrate that in India, green finance mobilizing instruments like green bonds or impact loans more easily attracts private capital toward renewable energies when households and SMEs benefit from expanded financial inclusion. This correlation between financing access and green mobilization is reinforced by Li et al. (2022), who establish that in Chinese provinces, a high digital finance index directly contributes to renewable energy demand growth, via alternative financing channels accessible to all.

In the context of BRICS and developing countries, Ali et al. (2023) reveal that digital financial inclusion is a central driver of energy transition: it reduces barriers to clean energy investment, stimulates green micro-credits, and aligns capital flows with COP objectives. This dynamic is also illustrated in Hossain et al. (2024) work, which highlights how the coupling between energy innovation, green finance, and digital inclusion fuels sustainable prosperity in several South Asian countries.

2.8. Toward Systemic Integration: Inclusion + Digitalization + Sustainability

Beyond finance alone, the effectiveness of sustainability policies increasingly relies on the interconnection between financial inclusion, digitalization, and energy transition. This is brilliantly shown by Liu et al. (2022), who emphasize that the combination of fintech, financial inclusion, and green finance significantly improves energy efficiency and accelerates renewable technology adoption.

Similarly, Asif et al. (2025) show that in G20 countries, the synergy between digitalization, clean energy consumption, and green financial instruments amplifies results in environmental sustainability, while mobilizing private finance toward sectors with strong positive externalities. Finally, Soltani (2024) proposes an innovative approach by combining advanced analytical methods and machine learning to measure the joint effects of digitalization, green finance, and foreign direct investment in renewable energy deployment.

3. Data and Methodology

In this section, we present the methodological framework adopted to empirically evaluate the impact of financial inclusion on sustainable development in Algeria. This approach relies on econometric foundations, combining variable selection, appropriate statistical data treatment, and application of the ARDL (Autoregressive Distributed Lag) model, recognized for its capacity to capture short and long-term dynamics between macroeconomic variables. The retained methodology follows both analytical and applied perspectives, aiming to produce economically interpretable and statistically reliable results.

3.1. Data

This study focuses on Algeria's case, due to the specificity of its economy, in transition from a hydrocarbon model toward a more diversified and sustainable structure. This choice is based on both structural and empirical considerations. Structurally, Algeria faces major

financial inclusion challenges, particularly in rural and semi-urban areas, where access to banking services remains limited (Bank of Algeria, 2023; Global Findex Database, 2022). Empirically, the availability, reliability, and coherence of economic and financial data between 2004 and 2022 justify the selection of this study period.

The data used in this research come from databases recognized for their methodological rigor and statistical reliability, notably the World Bank, the Bank of Algeria for domestic series, and the International Monetary Fund, and all these variables were transformed into natural logarithms. This transformation allows variance stabilization, correction of asymmetric distribution effects, and facilitates coefficient interpretation in elasticity terms, in accordance with methodological standards established in econometric work (Wooldridge, 2016; Gujarati & Porter, 2009).

3.1.1. Variable Specification

Dependent variable (Sustainable Development)

Gross Domestic Product per capita (GDP/capita, local currency, constant prices) - Used as a synthetic indicator of sustainable development, integrating economic growth adjusted for inflation (World Bank, 2023).

Although sustainable development is a multidimensional concept encompassing economic, social, and environmental dimensions, GDP per capita is widely used in empirical studies as a proxy due to its availability and its ability to capture long-term economic welfare and living standards. It reflects improvements in income, productivity, and economic capacity, which are essential components of sustainable development, especially in developing economies such as Algeria where data limitations constrain the use of composite indices.

Independent variables (Financial Inclusion)

- Money supply (M2/GDP): Measures liquidity available in the economy and its capacity to support structural investments. Financial inclusion passes through a stable and accessible monetary system (IMF, 2022).
- Private sector credit (% of GDP): Indicator of financial institutions' capacity to mobilize savings toward productive activities. Commonly used in inclusive growth studies (Levine, 2005).
- Bank deposits (% of GDP): Reflects population inclusion in formal savings circuits. Strong domestic deposit mobilization supports long-term project financing (Bank of Algeria, 2023).
- Number of automated teller machines (ATM per 100,000 adults): Proxy for digital financial infrastructure diffusion and physical access to banking services. Widely used in financial inclusion studies (Demirgüç-Kunt et al., 2022).

These variables are selected in coherence with recent empirical work using ARDL models to examine financial services' influence on sustainable development, such as those by Elfaki & Ahmed (2024) for Asia or Afful et al. (2025) for West Africa.

3.2. Econometric analysis

The ARDL (Autoregressive Distributed Lag) model is retained as the analysis tool to evaluate the impact of financial inclusion variables on sustainable development in Algeria. This choice is based on several methodological justifications:

- **Flexibility in the presence of mixed integration order series $I(0)$ and $I(1)$:** Unlike VAR and VECM models, ARDL allows working with non-stationary series provided none are integrated of order two (Pesaran et al., 2001).
- **Capacity to distinguish short-term and long-term dynamics:** This characteristic is essential for analyzing delayed structural effects and their asymmetric impacts.
- **Adaptability to small samples:** The ARDL model is reputed for producing robust estimations even with limited sample sizes, which is frequent in emerging economies (Narayan, 2005).

This approach is widely used in recent empirical work, as in Zhang & Guo (2024) for the Indian case, Huo et al. (2024) for emerging countries (E7), or Tang (2024) in the framework of institutional impact on biodiversity. It allows flexible modeling while integrating specificities of economies with partially developed financial infrastructures.

Econometric Treatment Steps

1. **Time series stationarity test:** Series stationarity is verified using the Augmented Dickey-Fuller (ADF) test. This test allows confirming that series are integrated at most of order one [$I(1)$], necessary condition for applying Pesaran's bounds cointegration test.
2. **ARDL model estimation by OLS (Ordinary Least Squares):** The model is then estimated using EViews 10 software. Optimal lags are selected via Akaike Information Criterion (AIC) to guarantee estimation efficiency.
3. **Long-term relationship verification:** The existence of a cointegration relationship is tested via the bounds test procedure. F-statistic significance allows confirming the existence of long-term equilibrium between financial inclusion and sustainable development.
4. **Model diagnostics:** Robustness tests (autocorrelation, heteroscedasticity, coefficient stability) are performed to guarantee statistical inference validity.

The adopted approach guarantees robust, rigorous, and econometrically reliable modeling of the link between financial inclusion and sustainable development in Algeria. By combining a data transformation strategy coherent with a well-founded ARDL approach, this research contributes to filling an important empirical gap concerning North African countries, while providing operational elements to economic decision-makers.

4. Results

4.1. Stationarity of Time Series

The Phillips-Perron test was used to evaluate the stationarity of the data series. The outcomes of this unit root test are presented in the table below:

Table (1): *The results of the ADF test (Augmented Dickey-Fuller)*

Variable	At Level		At First Difference	
	t-Statistic	Prob.	t-Statistic	Prob.
M2				
With Constant & Trend	-2.863860	0.1853	-5.949947	0.0001
With Constant	-1.327708	0.6064	-6.002632	0.0000
Without Constant & Trend	0.958846	0.9071	-5.916080	0.0000
CR				
With Constant & Trend	-1.220252	0.8914	-6.316435	0.0000
With Constant	-1.4340722	0.5552	-6.144873	0.0000
Without Constant & Trend	1.187409	0.9367	-5.916080	0.0000
DP				
With Constant & Trend	-3.016012	0.1416	-5.809730	0.0002
With Constant	-1.656527	0.4444	-5.896098	0.0000
Without Constant & Trend	-0.585181	0.8383	-5.916080	0.0000
ATM				
With Constant & Trend	-3.435720	0.0629		
With Constant	-4.244326	0.0020		
Without Constant & Trend	0.385396	0.7896		
GDP				
With Constant & Trend	-1.501475	0.8111	-6.599011	0.0000
With Constant	-2.355693	0.1609	-6.023776	0.0000
Without Constant & Trend	-1.059154	0.9212	-5.916080	0.0000

Source: Compiled by the author using Eviews 10

From Table 1, we observe that the time series test indicates that the number of ATMs is stationary at the level, while the other variables are stationary at the first difference. Since the time series differ in their order of integration, we will estimate the relationship between the dependent variable and the independent variables in the short and long term using the Autoregressive Distributed Lag (ARDL) model.

4.2. Estimation of the ARDL Model

4.2.1. ARDL Bounds Test for Co-integration

Table (2): *The results of the bounds test*

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
Asymptotic: n=1000				
F-statistic	4.200351	10%	1.9	3.01
k	4	5%	2.26	3.48
		2.5%	2.62	3.9
		1%	3.07	4.44

Source: Compiled by the author using Eviews 10

From the table above, we observe that the calculated F-statistic value is 4.20, which is greater than the upper bound critical values at the 5% significance level. Therefore, we accept the existence of a long-term equilibrium relationship between the independent and dependent variables, indicating that there is a cointegrating relationship.

4.2.2. The Empirical Results of ARDL Estimation

Table (3): *The Results of Short-Run ARDL Error Correction Model*

ARDL Error Correction Regression				
Dependent Variable: D(LPIB)				
Selected Model: ARDL(2, 2, 2, 2, 0)				
Case 1: No Constant and No Trend				
Date: 05/04/24 Time: 16:33				
Sample: 2004S1 2022S2				
Included observations: 36				
ECM Regression				
Case 1: No Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LPIB(-1))	-0.438195	0.163962	-2.672540	0.0133
D(LATM)	0.137612	0.015677	8.777862	0.0000
D(LATM(-1))	0.082502	0.023019	3.584036	0.0015
D(LCR)	0.048960	0.022188	2.206612	0.0372
D(LCR(-1))	0.089472	0.029866	2.995777	0.0063
D(LM2)	-0.228976	0.035734	-6.407725	0.0000
D(LM2(-1))	-0.250529	0.073066	-3.428786	0.0022
CointEq(-1)*	-0.028492	0.005756	-4.949954	0.0000
R-squared	0.826514	Mean dependent var		0.002827
Adjusted R-squared	0.783143	S.D. dependent var		0.015897
S.E. of regression	0.007403	Akaike info criterion		-6.780760
Sum squared resid	0.001534	Schwarz criterion		-6.428866
Log likelihood	130.0537	Hannan-Quinn criter.		-6.657939
Durbin-Watson stat	1.810658			

Source: Compiled by the author using Eviews 10

The results of the short-run ARDL model indicate that:

- The coefficient of return towards equilibrium is statistically significant and appears with a negative value estimated at -0.028492, which supports the existence of a long-term equilibrium relationship between the sustainable development index and the independent variables.
- The independent variables explain the dependent variable by more than 60%, as shown by the coefficient of determination (R^2) of 0.82 and the Adjusted R-squared (R^2 adj) of 0.78.
- The money supply to GDP is significant and has a negative impact on sustainable development in the short run.
- The ATM index and the private sector credit index are significant and have a positive impact on sustainable development in the short run.

Table (4): *Results of ARDL Long Run Coefficients*

Case 1: No Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LATM	0.388396	0.324342	1.197489	0.2428
LCR	-2.689054	0.749284	-3.588832	0.0015
LM2	6.344638	2.102935	3.017039	0.0060
LDP	-1.928156	2.057481	-0.937144	0.3580

Source: Compiled by the author using Eviews 10

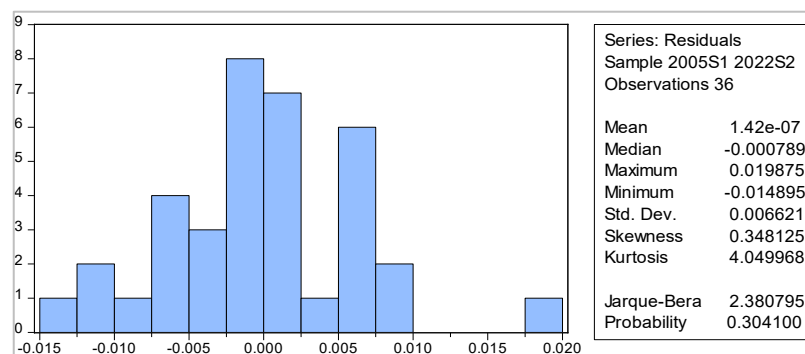
Table 4 shows that:

- The money supply index is significant and has a positive impact on the sustainable development index in the long run.
- Credit index negatively affects sustainable development in the long run.
- ATM and bank deposits do not affect sustainable development in the long run.

4.3. Diagnostic Tests

4.3.1. Normality Test

Figure (1): Results of Normality Test



Source: Compiled by the author using Eviews 10

The figure 01 shows the normal distribution test for the residuals, where all variables indicate that they follow the normal distribution according to the Jarque-Bera test, which shows that its probability value, estimated at 0.30, is greater than 5%.

4.3.2. Breusch-Godfrey Serial Correlation LM Test

Table (5): Results of Breusch-Godfrey Serial Correlation LM Test

Breusch-Godfrey Serial Correlation LM Test			
F-statistic	2.515753	Prob. F(2,22)	0.1038
Obs*R-squared	6.700855	Prob. Chi-Square(2)	0.0351

Source: Compiled by the author using Eviews 10

According to Table 5, the F statistic was estimated at 2.51 and was not significant because its probability reached 0.10 and is greater than the level of significance. Therefore, it can be said that the model is free from the problem of serial correlation.

4.3.3. Heteroskedasticity Test

Table (6): Results of Heteroskedasticity Test

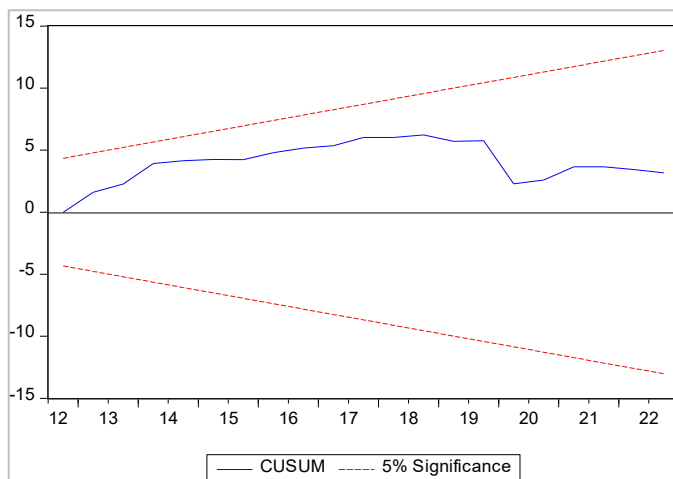
Heteroskedasticity Test: ARCH			
F-statistic	0.282935	Prob. F(1,33)	0.5983
Obs*R-squared	0.297532	Prob. Chi-Square(1)	0.5854

Source: Compiled by the author using Eviews 10

The results of the Heteroskedasticity Test show that the model is free from the problem of non-stationarity of variance, given that the probability of the F statistic was estimated at 0.59, which is greater than the significance level, while its value reached 0.28.

4.3.4. Structural Stability Test

Table (7): *Structural Stability Test*



Source: Compiled by the author using Eviews 10

The figure shows the stability of the model and the fit of the linear formula to the data at the 5% significance level, which indicates that there is no effect of shocks that reduce the quality of the model.

5. Discussion

The results obtained in this study concerning the impact of financial inclusion on sustainable development in Algeria, estimated by an ARDL model for the period 2004-2022, are globally coherent with recent literature. As highlighted in several cited works, financial inclusion plays an essential role as a catalyst for sustainable development, particularly in emerging and developing countries.

In our study, the immediate positive effect of automated teller machines (ATMs) on sustainable development in the short term corroborates the conclusions of Zhao and Zhao (2024), who emphasize the importance of digital financial innovations in reducing territorial inequalities and democratizing renewable energies. The absence of a significant long-term effect of ATM infrastructure and bank deposits may indicate that financial inclusion in Algeria remains largely superficial and access-oriented rather than usage-oriented. While the expansion of banking infrastructure improves short-term accessibility, it does not necessarily translate into sustained economic impact without effective financial usage, digital literacy, and integration into productive activities. This could indicate a need

to deepen digital financial inclusion policies and their long-term integration into Algeria's sustainable development strategy.

The positive short-term impact of private sector credit aligns with observations by Cen & Yin (2024), who affirm that credit access, combined with fintechs, enables environmental quality improvement by facilitating sustainable investments. The negative impact of private sector credit on sustainable development in the long run seems contradictory with certain Akono & Kemezang (2024) who notably show a positive synergy between fintech, credit, and energy transition in sub-Saharan economies. This negative effect reflects structural inefficiencies in credit allocation within the Algerian banking system. In a country-dominated banking structure, credit may be directed toward less productive or non-sustainable sectors, reducing its long-term developmental impact. Additionally, weak financial intermediation, limited risk assessment mechanisms, and the dominance of public banks may lead to suboptimal allocation of financial resources. This calls for a more rigorous regulatory framework.

These findings can also be interpreted through Financial Intermediation Theory, which suggests that the effectiveness of financial systems depends on their ability to allocate resources efficiently. The Algerian case highlights potential inefficiencies in this intermediation process.

The positive relationship between money supply and sustainable development in the long term, observed in our study, fits into a logic similar to that presented by Dai et al. (2025) who affirm that green finance and monetary policies favor low-carbon trajectories in BRICS countries. However, contrary to conclusions by other authors such as Fang et al. (2024), who insist on the significant role of financial digitalization in long-term sustainability. The negative short-term effect of money supply may be associated with inflationary pressures or inefficient liquidity allocation, where increased liquidity does not immediately translate into productive investment but may instead fuel consumption or speculative activities.

Furthermore, the absence of major diagnostic problems in our ARDL model, such as serial correlation or heteroscedasticity, reinforces methodological robustness and aligns our approach with methodological standards observed in Elfaki & Ahmed (2024), Tekin et al. (2024), and Afful et al. (2025).

From the perspective of Financial Inclusion Theory, access to financial services is expected to enhance economic participation, reduce inequality, and support sustainable development. The positive short-term effects observed in this study confirm this theoretical expectation. However, the lack of long-term significance for some variables suggests that access alone is insufficient; effective usage, financial literacy, and integration into productive sectors are crucial for achieving sustainable development.

The findings are also consistent with Endogenous Growth Theory, which highlights the importance of financial development, innovation, and human capital in sustaining long-term growth. The positive role of digital access (ATM) in the short run reflects how

financial infrastructure can stimulate economic participation and productivity. However, the absence of long-term effects indicates that such infrastructure must be complemented by effective financial usage, technological adoption, and institutional support to generate sustained development outcomes.

Overall, the results suggest that financial inclusion in Algeria generates short-term gains but faces structural limitations in achieving long-term sustainable development. This highlights the importance of strengthening institutional quality, improving financial intermediation efficiency, and promoting effective financial usage. Future research should further explore non-linear dynamics and incorporate broader sustainability indicators to provide a more comprehensive assessment.

6. Conclusion

In a context where sustainable development constitutes a strategic imperative for transitioning economies, this study empirically examined the relationship between financial inclusion and sustainable development in Algeria over the period 2004-2022. Through a rigorous methodological framework based on the ARDL model, the analysis sought to identify economic channels through which financial services notably money supply, bank credits, bank deposits, and digital service access influence the country's sustainable growth trajectory.

The econometric results highlight the existence of a positive and significant long-term relationship between several dimensions of financial inclusion and sustainable development. More precisely, private sector credit appears as an important short-term catalyst, although its long-term effect remains ambiguous due to structural inefficiencies in allocation, while ATM density constitutes an operational lever for democratizing access to financial services, particularly in under-banked areas.

Conversely, money supply, while having a positive long-term effect, shows a more moderate contribution, suggesting the necessity of a better-structured monetary environment more oriented toward productive uses.

Economic Implications and Recommendations

These results suggest that financial inclusion, when articulated with an integrated development strategy, can play a structuring role in Algeria's economic transformation. However, this dynamic cannot be fully operational without strong institutional accompaniment, notably in three strategic domains:

- **Financial Education:** Increased access to banking services does not guarantee their efficient use. It is imperative to develop financial literacy programs, particularly targeting young people, women, and rural populations. Better understanding of financial products favors more rational decision-making, reduces voluntary banking exclusion, and improves savings and credit management.

- **Banking Service Digitalization:** Physical infrastructure densification (ATMs, branches) must be completed by promoting inclusive digital solutions: mobile banking, electronic wallets, contactless payments. Digitization can considerably reduce financial intermediation costs and extend access to historically marginalized segments.
- **Green and Sustainable Finance:** Development of green financial products, such as green bonds or eco-responsible credits, can make financial inclusion and ecological transition converge. In this sense, green literacy becomes a complementary field to integrate into national economic education strategies.

Study Limitations

While this research brings significant contributions, it contains certain methodological and empirical limitations that should be highlighted:

- Certain key variables (e.g., digital finance or microfinance indicators) are not available at high frequency or with sufficient temporal coverage in Algeria. This limits the capacity to capture certain fine dynamics.
- Sustainable development being a multidimensional concept, using GDP per capita alone only partially captures social or ecological externalities. Including expanded indicators (poverty rates, CO₂ emissions, education) in future work would allow better representation.
- While robust, the ARDL model assumes a linear relationship between variables. However, certain financial inclusion effects may be non-linear or asymmetric (e.g., threshold effects, inverted U-curve), which would require using NARDL or MIDAS models in subsequent studies.
- The analysis remains centered on a univariate national framework. A comparative regional or multi-country approach (e.g., Algeria vs Morocco or Egypt) would offer a complementary view on structural specificities of the Algerian economy.

These findings confirm that the effectiveness of financial inclusion depends not only on access to financial services but also on the efficiency of financial intermediation and institutional quality, as emphasized in contemporary economic theory.

In conclusion, this research confirms the strategic role of financial inclusion as a driver of sustainable development in Algeria. It highlights the necessity of a holistic approach combining accessible finance, financial education, digital innovation, and green finance. To meet upcoming challenges and align with 2030 Agenda objectives, it is essential that public policies integrate this triple dimension economic, social, and environmental at the heart of their vision for national financial transformation. Ultimately, achieving sustainable development in Algeria requires moving beyond mere financial access toward an integrated model that combines efficiency, inclusion, and sustainability within a coherent institutional and policy framework.

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