

Assessing the Relationship between Renewable Energy Consumption and Economic Growth in Algeria (1990–2022): Evidence from an ARDL Approach

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Abstract

This study assesses the relationship between renewable energy consumption and economic growth in Algeria over the period 1990–2022 using the autoregressive distributed lag (ARDL) bounds-testing approach. Real GDP per capita is modelled as a function of renewable energy consumption, gross fixed capital formation, trade openness, employment, and fossil energy consumption. The bounds test confirms a long-run equilibrium relationship among the variables. Renewable energy consumption exhibits a positive but statistically insignificant long-run coefficient, whereas gross fixed capital formation and employment exhibit positive and statistically significant long-run relationships with economic growth. In the short run, the contemporaneous change in renewable energy consumption is insignificant, while its first and second lagged changes are negative and statistically significant. The error-correction term is negative and highly significant, confirming adjustment toward long-run equilibrium. Overall, the findings indicate that renewable energy had not yet reached the scale

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and degree of integration into Algeria's productive structure required to generate a statistically identifiable contribution to economic growth. Strengthening this contribution requires closer integration of renewable-energy deployment with productive investment, domestic value creation, technological capabilities, infrastructure, and human-capital development.

Keywords: Renewable energy consumption; Economic growth; Algeria; ARDL; Cointegration; Energy transition.

JEL Classification : C22; O44; Q42; Q43.

1. Introduction

The transformation of energy systems has broadened the economic debate surrounding renewable energy beyond its role as a substitute for fossil fuels or a means of reducing environmental pressures. Renewable-energy development increasingly intersects with investment, technological change, industrial activity, employment, energy security, and economic growth. Its economic relevance therefore depends not only on resource availability or installed capacity, but also on the extent to which renewable-energy investment is integrated into domestic productive activity.

Renewable energy can interact with economic growth through several channels. Investment in generation facilities, electricity networks, storage systems, and related infrastructure contributes to capital formation, while renewable deployment may improve energy security, stimulate technological learning, and generate activity in construction, manufacturing, operation, and maintenance. However, these effects depend on the structure of the economy and the domestic content of investment; where technologies, equipment, and services are predominantly imported, a significant share of expenditure may not translate directly into domestic value added.

The empirical literature provides no uniform conclusion regarding the renewable energy–growth relationship. Four principal hypotheses are generally distinguished: the growth hypothesis, whereby renewable energy contributes to economic growth; the conservation hypothesis, whereby economic growth drives energy consumption; the feedback hypothesis, implying bidirectional causality; and the neutrality hypothesis, indicating no causal relationship. Sebri's (2015) meta-analysis confirms the coexistence of these configurations and shows that differences in model specification, data characteristics, estimation techniques, and levels of economic development contribute to heterogeneous findings (Sebri, 2015).

Cross-country evidence reinforces this heterogeneity. Bhattacharya et al. (2016), examining 38 major renewable-energy-consuming economies over 1991–2012, find a statistically significant positive long-run effect of renewable energy on output in 57% of the countries considered (Bhattacharya et al., 2016). This suggests that productive, technological, institutional, and energy structures influence whether renewable-energy expansion translates into measurable economic gains.

The issue is particularly relevant for Algeria, which possesses substantial renewable-energy potential, especially solar resources, while its economy and energy system remain strongly dependent on hydrocarbons. Reviews of Algeria's energy transition emphasize both its considerable renewable-resource potential and the persistence of fossil-fuel dominance in the national energy system (Stambouli, 2011; Bouznit et al., 2020; Zahraoui et al., 2021). It is therefore important to distinguish renewable-energy potential and installed capacity from actual renewable energy consumption: substantial technical potential and ambitious targets do not necessarily imply that renewable energy has reached a scale sufficient to generate a measurable macroeconomic relationship with output.

Existing empirical evidence for Algeria illustrates this distinction. Amri (2017), using data for 1980–2012, identifies a long-run relationship among real GDP, capital, renewable energy consumption, and non-renewable energy consumption. The ARDL estimates indicate significant contributions from capital and non-renewable energy, whereas renewable energy does not exhibit a statistically significant

effect on economic growth (Amri, 2017). From an environmental perspective, Bélaïd and Youssef (2017) find that renewable electricity consumption contributes to improved environmental quality in Algeria, while noting that renewable electricity generation had not yet reached a level capable of making a substantial contribution to emissions reduction (Bélaïd & Youssef, 2017).

Against this background, this study assesses the relationship between renewable energy consumption and economic growth in Algeria over 1990–2022. Real GDP per capita is modelled as a function of renewable energy consumption, gross fixed capital formation, trade openness, employment, and fossil energy consumption. This multivariate specification allows the renewable-energy relationship to be assessed while controlling for capital accumulation, labour, external economic integration, and the continuing role of conventional energy.

The central research question is therefore:

To what extent is renewable energy consumption associated with economic growth in Algeria, and how does this relationship differ between the short run and the long run?

The study contributes to the Algerian literature by examining this relationship within a multivariate dynamic framework that explicitly distinguishes long-run equilibrium effects from short-run adjustments. The ARDL approach is appropriate because the unit-root analysis confirms that none of the variables is integrated of order two.

The remainder of the paper is organized as follows. Section 2 presents the theoretical framework and relevant empirical literature. Section 3 describes the data and methodology, Section 4 reports and discusses the empirical results, and Section 5 concludes with the main policy implications.

2. Theoretical Framework and Literature Review

2.1. Renewable Energy and Economic Growth

Economic growth reflects a sustained expansion of an economy's real productive capacity. In conventional growth theory, output is determined principally by capital, labour, and technological progress. The neoclassical framework developed by Solow (1956) emphasizes capital accumulation and labour as fundamental productive inputs while assigning technological progress a central role in sustained long-run improvements in output per worker (Solow, 1956).

Energy complements these productive factors because industrial production, transportation, infrastructure, capital equipment, and a wide range of services require energy to operate. Changes in the availability, reliability, cost, and composition of energy supply can therefore influence productive activity.

Renewable energy introduces additional mechanisms into this relationship. Investment in renewable generation can contribute to gross fixed capital formation through power plants, networks, storage, and supporting infrastructure. When renewable-energy deployment is accompanied by domestic engineering, construction, manufacturing, operation, and maintenance, it may generate additional value added and employment. Technological learning and the development of energy-related capabilities can further reinforce these effects.

The economic effect is nevertheless conditional rather than automatic. Renewable-energy projects that depend heavily on imported technology and equipment generate a different domestic economic impact from projects embedded in local industrial and technological value chains. The relationship between renewable energy and growth may therefore vary considerably across economies even when renewable investment increases.

In hydrocarbon-exporting countries, renewable energy may also interact with economic performance through the composition of domestic energy consumption. Increasing renewable supply can potentially

reduce the amount of conventional energy required to satisfy domestic demand. However, whether such changes produce a measurable aggregate growth relationship depends on the scale of renewable deployment and the structure of the wider economy.

2.2. Energy–Growth Hypotheses

The energy–growth literature commonly distinguishes four causal hypotheses: growth, conservation, feedback, and neutrality (Sebri, 2015).

Under the growth hypothesis, causality runs from energy consumption to economic growth. Energy is therefore treated as an economically important input whose availability can constrain or support productive activity.

Under the conservation hypothesis, causality runs from economic growth to energy consumption. Economic expansion increases demand for energy, but energy consumption does not independently drive growth.

The feedback hypothesis implies bidirectional causality, meaning that energy consumption affects economic activity while economic activity simultaneously influences energy demand.

The neutrality hypothesis implies that no statistically identifiable causal relationship exists between energy consumption and economic growth.

The existence of these competing hypotheses demonstrates why the direction and magnitude of the renewable energy–growth relationship should be established empirically rather than assumed beforehand. Sebri (2015) shows precisely that the empirical literature supports different hypotheses depending on methodological and country-specific characteristics.

2.3. International Empirical Evidence

International evidence remains heterogeneous. Apergis and Payne (2010) examine renewable energy consumption and economic growth in a panel of OECD countries and identify long-run relationships between renewable energy consumption and output. Their work contributed to the development of the empirical literature examining renewable energy within production-function frameworks.

Bhattacharya et al. (2016) subsequently investigate 38 major renewable-energy-consuming countries over 1991–2012. Their results establish cross-sectional dependence and heterogeneity and show that renewable energy consumption has a statistically significant positive long-run effect on output for 57% of the countries examined (Bhattacharya et al., 2016). The result is particularly important because it demonstrates that even among major renewable-energy economies, a positive statistically significant relationship is not universal.

Marinaş et al. (2018), examining Central and Eastern European countries, likewise find that the causal relationship between renewable energy consumption and economic growth varies across economies. The broader literature therefore indicates that institutional characteristics, economic structure, energy composition, methodological choices, and the scale of renewable deployment can influence empirical findings.

Sebri (2015) provides a systematic explanation for this heterogeneity. Using a meta-analysis of the renewable energy consumption–economic growth literature, the study finds that the probability of obtaining different causal hypotheses varies with model specification, data characteristics, cointegration and causality techniques, and the development level of the countries examined (Sebri, 2015).

More recent research has also questioned the assumption that the renewable energy–growth relationship must be linear. Threshold evidence suggests that the economic effect of renewable energy may depend on the level of renewable-energy use itself, particularly in developing economies. This

reinforces the proposition that renewable-energy expansion must reach sufficient scale and integration before a stable macroeconomic relationship necessarily emerges.

2.4. Evidence from Algeria and Research Positioning

The Algerian literature remains relatively limited compared with the broader international literature. Amri (2017) provides one of the closest empirical benchmarks to the present study. Using annual data for 1980–2012, the study examines real GDP, real capital, renewable energy consumption per capita, and non-renewable energy consumption. Cointegration analysis establishes a long-run relationship among the variables. However, both the short- and long-run ARDL estimates indicate that renewable energy does not exert a statistically significant effect on economic growth, whereas capital and non-renewable energy contribute significantly to output (Amri, 2017).

The causality results reported by Amri (2017) are more nuanced than the coefficient estimates, illustrating the importance of distinguishing between the statistical significance of conditional regression coefficients and the direction of causality. The present study consequently focuses primarily on the estimated long- and short-run ARDL relationships rather than treating causality and coefficient significance as interchangeable concepts.

Bélaïd and Youssef (2017) examine the Algerian case from an environmental perspective. Their analysis identifies a long-run cointegrating relationship among economic growth, renewable electricity consumption, non-renewable electricity consumption, and environmental degradation. Renewable electricity consumption is associated with improved environmental quality, whereas economic growth and non-renewable electricity consumption exert adverse environmental effects (Bélaïd & Youssef, 2017). Although their dependent variable and principal research question differ from those of the present study, their results confirm the importance of distinguishing renewable and conventional energy in empirical analysis of Algeria.

Elbadri et al. (2023) provide more recent evidence using a Fourier-Bootstrap ARDL approach for Algeria over 1990–2018. Their study examines renewable energy use, economic growth, and CO₂ emissions and identifies a long-run relationship among the variables. The causality analysis reports one-way causality from economic growth to renewable energy use, providing evidence consistent with the conservation hypothesis.

Taken together, the literature does not establish a uniform renewable energy–growth relationship for Algeria. This provides the empirical motivation for reassessing the relationship using a specification that simultaneously controls for capital formation, trade openness, employment, and fossil energy consumption. The present model therefore evaluates renewable energy within the broader productive and energy structure of the Algerian economy rather than in isolation.

3. Data and Methodology

3.1. Data and Variables

The study uses annual data covering the period 1990–2022. Following the selected lag structure, the effective ARDL estimation sample covers 1993–2022, with 30 observations.

All variables are transformed into natural logarithms before estimation.

Table 1. Variables and Data Sources

Symbol	Variable	Measurement	Source
GDP	Real GDP per capita	Constant US dollars (base-year prices)	World Bank, WDI
REC	Renewable energy	Million tonnes of oil	IEA and IRENA

	consumption	equivalent	Statistics
GFCF	Gross fixed capital formation	Constant US dollars	World Bank, WDI
TRADE	Trade openness	% of GDP	World Bank, WDI
EMP	Employment rate	% of active population	World Bank, WDI
FEC	Fossil energy consumption	Million tonnes of oil equivalent	WDI series as compiled via Macrotrends

Source: Author's compilation from the study database and the original data sources.

The dependent variable is real GDP per capita. Renewable energy consumption is the principal explanatory variable. Gross fixed capital formation captures capital accumulation, employment represents the labour dimension of production, trade openness controls for external economic integration, and fossil energy consumption captures the continuing role of conventional energy within Algeria's productive structure.

3.2. Model Specification

The empirical relationship is specified as:

$$\ln GDP_t = \alpha_0 + \beta_1 \ln REC_t + \beta_2 \ln GFCF_t + \beta_3 \ln TRADE_t + \beta_4 \ln EMP_t + \beta_5 \ln FEC_t + \varepsilon_t$$

where GDP denotes real GDP per capita, REC renewable energy consumption, GFCF gross fixed capital formation, TRADE trade openness, EMP employment, and FEC fossil energy consumption.

Because the variables are expressed in logarithms, the estimated long-run coefficients can be interpreted as elasticities, subject to statistical significance and the validity of the estimated long-run relationship.

3.3. Econometric Strategy

The empirical analysis proceeds in several stages. First, the time-series properties of the variables are examined using the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit-root tests. The purpose of this stage is to establish the order of integration and, critically, to verify that no variable is integrated of order two, I(2), because the standard ARDL bounds-testing critical values are not valid in the presence of I(2) variables.

The unit-root results show that the variables become stationary after first differencing and are therefore integrated of order one, I(1). This permits application of the ARDL bounds-testing framework.

The ARDL approach developed by Pesaran, Shin, and Smith (2001) is then used to investigate whether a long-run level relationship exists among the variables. The method estimates both lagged levels and short-run differences and permits the long-run equilibrium relationship to be distinguished from short-run adjustment.

The general error-correction representation can be expressed as:

$$\Delta \ln GDP_t = \alpha + \sum \phi_i \Delta \ln GDP_{t-i} + \sum \theta_j \Delta \ln REC_{t-j} + \sum \gamma_k \Delta \ln GFCF_{t-k} + \sum \delta_l \Delta \ln TRADE_{t-l} + \sum \eta_m \Delta \ln EMP_{t-m} + \sum \psi_n \Delta \ln FEC_{t-n} + \lambda ECT_{t-1} + \varepsilon_t$$

where ECT_{t-1} represents the lagged error-correction term and λ measures the adjustment toward long-run equilibrium following a short-run disturbance.

The existence of cointegration is assessed using the ARDL bounds test. The null hypothesis of no level relationship is rejected when the calculated F-statistic exceeds the relevant upper-bound critical value.

The appropriate lag structure is selected automatically using the Akaike Information Criterion (AIC). Following estimation of the long- and short-run relationships, diagnostic tests are employed to examine residual serial correlation, conditional heteroskedasticity, residual normality, and parameter stability.

4. Empirical Results and Discussion

4.1. Unit-Root Tests and ARDL Model Selection

The ADF and PP tests indicate that the variables included in the economic model are non-stationary in levels but become stationary after first differencing. They are therefore treated as I(1). Most importantly for the ARDL methodology, none of the variables is I(2).

Following the presentation strategy used in applied ARDL studies, the extensive raw EViews output is not reproduced in full; the result needed for the econometric decision is summarized in Table 2.

Table 2. Summary of Unit-Root Test Results

Variable	ADF/PP conclusion	Order of integration
lnGDP	Stationary after first difference	I(1)
lnREC	Stationary after first difference	I(1)
lnGFCF	Stationary after first difference	I(1)
lnTRADE	Stationary after first difference	I(1)
lnEMP	Stationary after first difference	I(1)
lnFEC	Stationary after first difference	I(1)

Source: Author's calculations based on EViews 14 unit-root outputs.

The stationarity results therefore satisfy the integration-order requirement for applying the ARDL bounds-testing approach.

Automatic lag selection allows a maximum of three lags for the dependent variable and regressors. EViews evaluates 3,072 candidate specifications, and the Akaike Information Criterion selects ARDL(2,3,3,0,1,1) as the preferred specification. The final model uses 30 effective observations for 1993–2022.

The estimated model exhibits a high overall explanatory fit, with $R^2 = 0.993809$ and adjusted $R^2 = 0.987176$. The overall F-statistic equals 149.8263 with a probability of 0.0000. These statistics indicate strong joint explanatory power, although the very high R^2 in a dynamic time-series model should not itself be interpreted as evidence of causal validity.

4.2. Bounds Test for Cointegration

The bounds test is used to determine whether the variables share a long-run equilibrium relationship.

Table 3. ARDL Bounds-Test Results

Statistic	Value
F-statistic	6.089781
Upper bound I(1), 10%	3.517
Upper bound I(1), 5%	4.193

Upper bound I(1), 1%	5.761
Decision	Cointegration confirmed

Source: Author's calculations based on EViews 14 bounds-test output.

The calculated F-statistic of 6.089781 exceeds the upper-bound critical value even at the 1% significance level. The null hypothesis of no level relationship is therefore rejected, confirming the existence of a long-run equilibrium relationship among real GDP per capita, renewable energy consumption, gross fixed capital formation, trade openness, employment, and fossil energy consumption.

This result concerns the variables jointly. It does not imply that every individual long-run coefficient is statistically significant.

4.3. Long-Run Relationship

The long-run estimates reveal important differences across the explanatory variables.

Table 4. Long-Run ARDL Estimates

Variable	Long-run coefficient	p-value	Inference
lnREC	0.102929	0.2061	Positive, statistically insignificant
lnGFCF	0.529558	0.0000	Positive, statistically significant
lnTRADE	0.222312	0.2056	Positive, statistically insignificant
lnEMP	1.089125	0.0060	Positive, statistically significant
lnFEC	2.293899	0.8806	Positive, statistically insignificant

Source: Author's calculations based on EViews 14 long-run ARDL output.

The coefficient on renewable energy consumption is positive but statistically insignificant. Accordingly, the results do not provide sufficient statistical evidence that renewable energy consumption exerted an independent long-run effect on real GDP per capita over the period examined. The positive sign indicates the direction of the estimated relationship, but the probability value does not permit rejection of the null hypothesis at conventional significance levels.

This finding is consistent with the evidence reported by Amri (2017) for Algeria. Using an earlier sample, Amri finds that renewable energy consumption does not have a statistically significant short- or long-run effect on economic growth, whereas capital and non-renewable energy are significant determinants (Amri, 2017).

The result should not be interpreted as evidence that renewable energy has no economic relevance. Rather, it indicates that renewable energy consumption had not reached a scale or degree of productive integration sufficient for its individual coefficient to be statistically distinguishable from zero within the estimated specification.

Gross fixed capital formation produces the strongest long-run result. Its coefficient is positive and statistically significant, indicating that capital accumulation is closely associated with higher real GDP

per capita. This result is economically consistent with the central role assigned to productive capital in growth theory and highlights the importance of investment in explaining Algeria's long-run economic performance.

Employment also exhibits a positive and statistically significant long-run coefficient (1.089125; $p = 0.0060$), indicating a positive long-run association between employment and real GDP per capita. Trade openness and fossil energy consumption are positive but statistically insignificant in the estimated long-run relationship.

The long-run results therefore indicate that the existence of cointegration among the variables does not translate into statistical significance for every determinant. Gross fixed capital formation and employment exhibit statistically significant positive long-run coefficients, while the renewable-energy coefficient remains positive but statistically insignificant.

4.4. Short-Run Dynamics and Error Correction

The short-run ARDL error-correction representation provides additional information concerning the dynamic response of economic growth.

Table 5. Short-Run Dynamics and Error-Correction Model

Variable	Coefficient	Std. Error	t-statistic	p-value
$\Delta \ln \text{GDP}(-1)$	0.530595	0.134789	3.936487	0.0008
$\Delta \ln \text{REC}$	0.005312	0.039549	0.134315	0.8945
$\Delta \ln \text{REC}(-1)$	-0.176580	0.040299	-4.381718	0.0003
$\Delta \ln \text{REC}(-2)$	-0.140394	0.046677	-3.007775	0.0070
$\Delta \ln \text{GFCF}$	0.546560	0.086406	6.325465	0.0000
$\Delta \ln \text{GFCF}(-1)$	-0.367724	0.113867	-3.229424	0.0042
$\Delta \ln \text{GFCF}(-2)$	-0.233983	0.080923	-2.891426	0.0090
$\Delta \ln \text{EMP}$	0.373402	0.422240	0.884335	0.3870
$\Delta \ln \text{FEC}$	60.02636	18.95278	3.167154	0.0048
$\text{ECT}(-1)$	-1.392152	0.178396	-7.803705	0.0000

Source: Author's calculations based on EViews 14 ARDL-ECM output.

The contemporaneous change in renewable energy consumption has a small positive coefficient of 0.005312, but it is statistically insignificant ($p = 0.8945$). By contrast, the first and second lagged changes in renewable energy consumption are negative and statistically significant, with coefficients of -0.176580 and -0.140394, respectively.

These short-run negative coefficients should not be interpreted mechanically as evidence that renewable-energy development harms economic growth. They represent conditional dynamic responses

within the estimated ARDL system. During the period examined, renewable-energy expansion remained limited relative to the size of the conventional energy system, and renewable investment was not yet deeply embedded in domestic industrial value chains. Adjustment costs, import dependence, infrastructure requirements, and the relatively small initial scale of renewable deployment can therefore contribute to short-run dynamics that differ from the estimated long-run direction.

Gross fixed capital formation exhibits strong short-run effects. Its contemporaneous change is positive and highly significant, whereas its first and second lagged changes are negative and significant. This pattern suggests substantial dynamic adjustment in the relationship between investment and output rather than a purely contemporaneous response.

The contemporaneous change in fossil energy consumption is positive and statistically significant. This result reflects the continuing short-run role of conventional energy in Algeria's existing productive structure. It should not be interpreted as evidence that long-term dependence on fossil fuels is economically optimal; rather, it describes the relationship observed within the historical structure covered by the sample.

The error-correction term is $ECT_{t-1} = -1.392152$, $p = 0.0000$. Its negative and highly statistically significant coefficient confirms the presence of an error-correction mechanism and supports the long-run relationship identified by the bounds test. Because the coefficient is below -1 , adjustment is not monotonic. Instead, deviations from equilibrium are corrected through an oscillatory or overshooting adjustment process before convergence toward the long-run equilibrium.

4.5. Diagnostic and Stability Tests

Consistent with the presentation strategy of the methodological reference, the principal diagnostic statistics are consolidated in one table, while residual normality and coefficient stability are shown graphically using the original EViews outputs.

Table 6. Diagnostic Tests

Diagnostic test	Statistic / result	Probability	Interpretation
Breusch–Godfrey LM – F-statistic	1.741420	0.2168	H_0 not rejected using F-form
Breusch–Godfrey LM – Obs*R ²	6.748451	0.0342	H_0 rejected using LM χ^2 form
ARCH – F-statistic	0.773781	0.3868	No ARCH evidence
ARCH – Obs*R ²	0.807944	0.3687	No ARCH evidence
Jarque–Bera	0.749575	0.687435	Normality not rejected

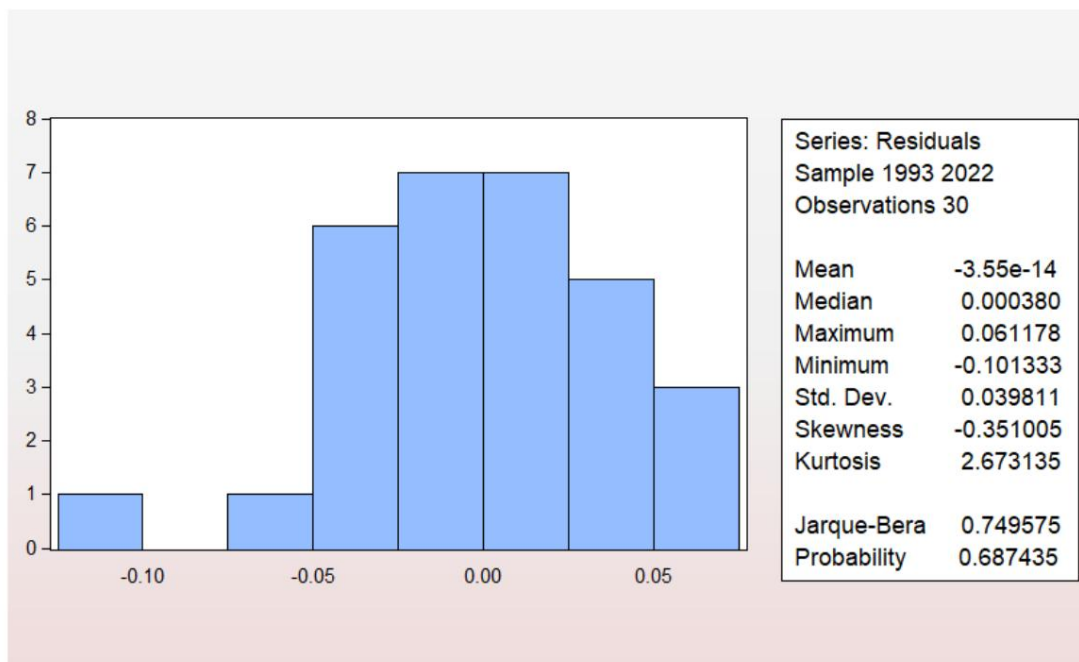
Source: Author's calculations based on EViews 14 diagnostic-test outputs.

The Breusch–Godfrey test requires careful interpretation. The F-form produces a probability of 0.2168, whereas the Obs*R² form produces a probability of 0.0342. The two statistics therefore lead to different decisions at the 5% level. Rather than suppressing this discrepancy, the present study reports both results. Consequently, the residual diagnostics do not justify an unequivocal statement that serial correlation is completely absent.

The ARCH test provides no evidence of autoregressive conditional heteroskedasticity. Both the F-statistic probability (0.3868) and the Obs*R² probability (0.3687) exceed conventional significance levels.

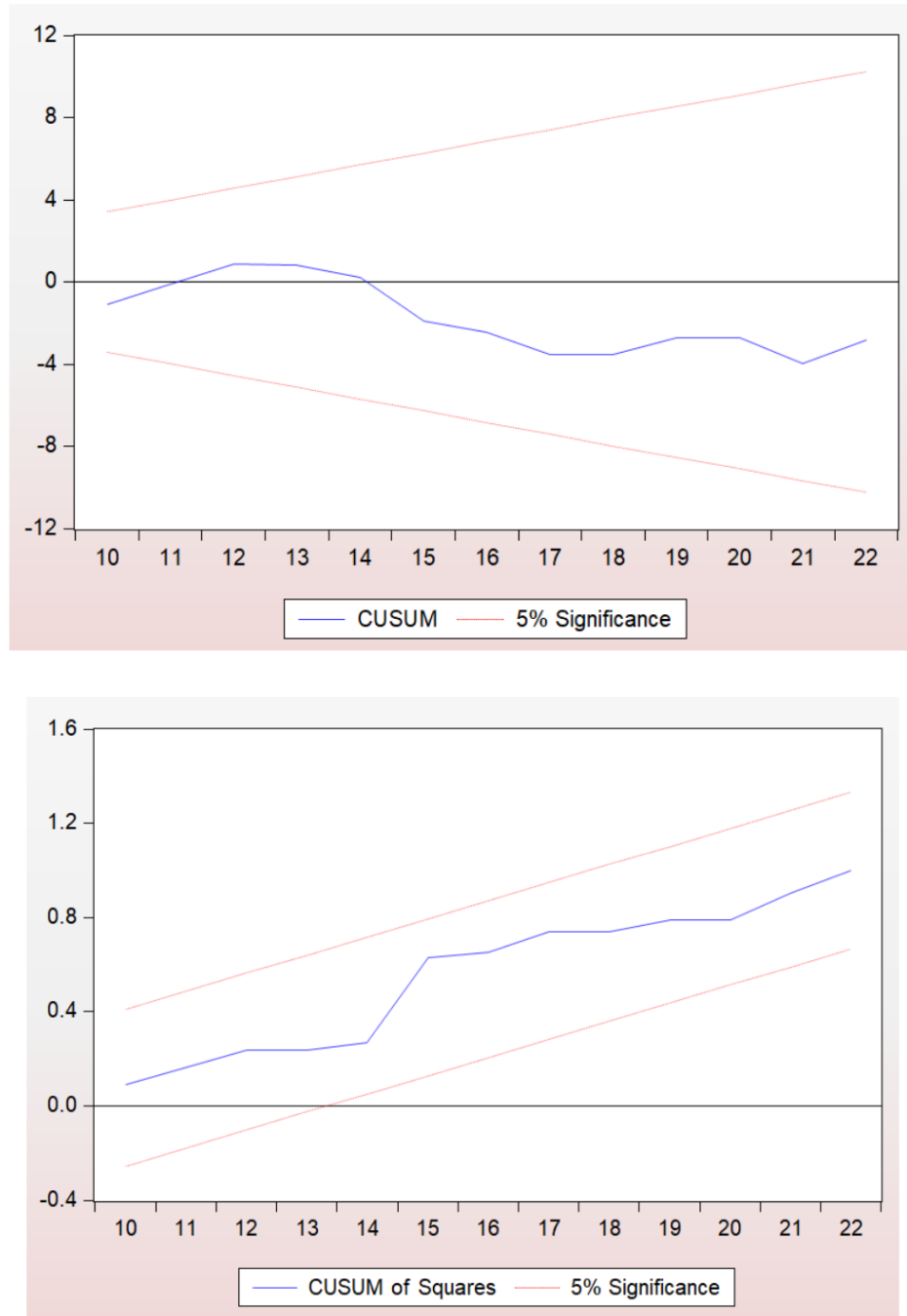
The Jarque–Bera statistic equals 0.749575, with a probability of 0.687435. The null hypothesis of normally distributed residuals is therefore not rejected.

Figure 1. Normality Test of Residuals



Source: EViews 14 output from the economic model.

Figure 2. Structural Stability of the ARDL-ECM Coefficients (CUSUM and CUSUM of Squares)



Source: EViews 14 output from the economic model.

Both the CUSUM and CUSUM of Squares statistics remain within the 5% critical boundaries over the reported period. These tests therefore provide no evidence of parameter instability in the estimated model.

4.6. Discussion of the Main Findings

The empirical results yield three principal conclusions.

First, the variables share a long-run equilibrium relationship, as demonstrated by the bounds-test statistic. This confirms that real GDP per capita, renewable energy consumption, capital formation, trade openness, employment, and fossil energy consumption are jointly linked over the long run.

Second, the individual long-run coefficient on renewable energy consumption is positive but statistically insignificant. The empirical evidence therefore does not establish renewable energy consumption as an independent statistically significant long-run determinant of economic growth in Algeria during the study period.

This result is broadly consistent with Amri (2017), whose Algerian ARDL analysis likewise reports an insignificant renewable-energy coefficient while finding stronger evidence for capital and non-renewable energy (Amri, 2017). It is also compatible with the broader international literature showing that the renewable energy–growth relationship is heterogeneous rather than universal. Sebri (2015) demonstrates that empirical findings vary according to country characteristics, data, specification, and econometric methodology, while Bhattacharya et al. (2016) find a significant positive long-run renewable-energy effect in only part of their country sample (Sebri, 2015; Bhattacharya et al., 2016).

Third, gross fixed capital formation provides the most robust positive long-run evidence in the model, while employment also exhibits a positive and statistically significant long-run coefficient. These results suggest that capital accumulation and employment were more clearly associated with Algeria's long-run economic performance than renewable-energy consumption during the period considered.

The limited statistical contribution of renewable energy can be interpreted in the context of Algeria's energy transition. Renewable-energy potential is substantial, but potential itself does not generate economic output. For renewable energy to produce a broad macroeconomic contribution, investment must reach sufficient scale and generate domestic linkages through construction, engineering, manufacturing, operation, maintenance, infrastructure, technological learning, and skilled employment.

If a large share of renewable-energy equipment and technology is imported, the domestic multiplier associated with investment is reduced. Similarly, where renewable generation represents only a limited part of the overall energy system, its aggregate contribution may remain too small to be identified statistically against the much larger conventional-energy sector.

The short-run results reinforce this interpretation. The contemporaneous renewable-energy coefficient is insignificant, while the first and second lagged changes are negative and significant. These coefficients describe the transitional dynamics observed in the historical data and should not be transformed into a general conclusion that renewable energy reduces growth. The long-run coefficient remains positive, although statistically insignificant.

The findings consequently point toward an important distinction between renewable-energy expansion and renewable-energy-based productive transformation. Increasing generation capacity can alter the energy mix, but stronger economic effects require the energy transition to generate investment, technological capabilities, domestic production, employment, and value added.

This distinction is particularly important for Algeria. Renewable-energy policy should therefore not be assessed exclusively in megawatts of installed capacity. Its economic performance should also be evaluated through domestic value added, local content, employment creation, technological capabilities, private investment, and the development of energy-related industrial and service activities.

5. Conclusion and Policy Implications

This study assessed the relationship between renewable energy consumption and economic growth in Algeria over the period 1990–2022 using an ARDL framework. Following the selected lag structure, the effective estimation sample covered 1993–2022.

The bounds test confirms the existence of a long-run equilibrium relationship among the variables. In the long run, renewable energy consumption has a positive but statistically insignificant coefficient, indicating insufficient evidence that it constituted an independent determinant of real GDP per capita during the period examined. Gross fixed capital formation shows the strongest positive and statistically significant relationship with economic growth, while employment is also positive and statistically significant. Trade openness and fossil energy consumption remain statistically insignificant in the long run.

In the short run, the contemporaneous change in renewable energy consumption is statistically insignificant, whereas its first and second lagged changes are negative and significant. Gross fixed capital formation displays significant contemporaneous and lagged effects, while fossil energy consumption is statistically significant. The error-correction coefficient (-1.392152) is negative and highly significant, confirming adjustment toward long-run equilibrium and indicating an overshooting adjustment process.

The diagnostic results are generally supportive of the estimated model. The ARCH test provides no evidence of conditional heteroskedasticity, the Jarque–Bera test does not reject residual normality, and the CUSUM and CUSUMSQ statistics remain within the 5% stability bounds. However, the Breusch–Godfrey test produces mixed results across its F and LM forms; therefore, the absence of serial correlation cannot be stated unequivocally.

Overall, the findings indicate that renewable energy consumption had not yet reached a scale and degree of integration into Algeria's productive structure sufficient to generate a statistically identifiable long-run relationship with economic growth. This does not imply that renewable energy lacks economic value; rather, its economic contribution depends on its integration into domestic investment, production, technological capabilities, and value creation.

Accordingly, the main policy implications are:

- Integrate renewable-energy policy with industrial and productive policy to strengthen its contribution to domestic value added.
- Promote domestic capabilities in engineering, installation, operation, maintenance, and, where economically viable, local production of renewable-energy components.
- Strengthen electricity networks, storage, system flexibility, and grid management to support the efficient integration of renewable generation.
- Develop relevant human capital through university and vocational programmes aligned with the technical, engineering, digital, and energy-system skills required by the sector.
- Evaluate renewable-energy programmes using economic as well as capacity indicators, including domestic value added, local content, employment, private investment, technological learning, and national supply-chain development.

The findings should nevertheless be interpreted in light of the effective sample of 30 annual observations and the relatively rich lag structure of the selected ARDL model. Future research could explicitly account for structural breaks, examine nonlinear specifications such as NARDL or Fourier-based ARDL models, and distinguish among renewable-energy technologies and their effects on industrial production, employment, technological development, and domestic value added.

The central conclusion is that renewable-energy potential alone is insufficient to generate a measurable contribution to economic growth. For Algeria, the economic value of the energy transition will depend increasingly on transforming renewable-energy expansion into domestic investment, productive activity, technological capabilities, employment, and value creation.

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