






“Renewable energy and economic growth in Morocco: Exploring the short- and long-run relationships”

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RENEWABLE ENERGY AND ECONOMIC GROWTH IN MOROCCO: EXPLORING THE SHORT- AND LONG-RUN RELATIONSHIPS

Abstract

This study examines the relationship between renewable energy consumption and economic growth in Morocco, while accounting for trade openness and CO₂ emissions per capita. Using annual data covering the period 1990–2024 and applying the Autoregressive Distributed Lag (ARDL) approach, the analysis captures both short-run dynamics and long-run relationships among the variables. The empirical results proved a long-term equilibrium relationship, as the bounds test rejects the null hypothesis of no cointegration, with the calculated F-statistic exceeding the upper critical bound I (1) at 10%, 5%, and 1% significance levels, and the error correction term being negative and highly significant (ECT = -0.2909), indicating that approximately 29% of short-run deviations from equilibrium are corrected each year. In the short term, the effects of renewable energy consumption on economic growth are mixed and largely delayed: while contemporaneous changes are not statistically significant, a positive and significant effect emerges after two periods. Trade openness exerts a positive and statistically significant influence with lagged effects, suggesting that increased trade activity stimulates economic growth in the short term. By contrast, CO₂ emissions per capita show an immediate positive but insignificant effect, followed by delayed negative and significant effects, reflecting short-term growth gains accompanied by subsequent environmental pressures. In the long run, renewable energy consumption and CO₂ emissions per capita are associated with a positive and statistically significant effect on economic growth, whereas the long-run impact of trade openness, despite a positive coefficient, remains statistically insignificant.

Keywords

renewable energies, economic growth, Morocco, ARDL, CO₂ emissions

JEL Classification

Q01, Q42, Q48

INTRODUCTION

Energy plays a fundamental role in the dynamics of global economic growth. Beyond being a key factor of production, it constitutes a central driver of industrialization, technological innovation, and social development. However, the persistent reliance on fossil fuels, particularly oil, natural gas, and coal, has generated significant environmental imbalances and heightened vulnerability to fluctuations in the global energy market. In response to these challenges, the United Nations has proclaimed the period from 2014 to 2024 as the Decade of Sustainable Energy for All. Through this initiative, the United Nations aims to promote universal access to clean, affordable, and reliable energy while supporting economic development and environmental protection. This international commitment reflects a collective effort to rethink the global energy model by integrating sustainability, energy efficiency, and technological innovation as core pillars.

In Africa, energy-related issues are particularly acute. Despite the continent's vast renewable potential, estimated by the International Renewable Energy Agency in 2021 at more than 300 GW for solar and 250 GW for wind energy, renewable sources still represent only a small share of total energy consumption. According to the African Development Bank (2022), fossil fuels continued to dominate Africa's energy supply, accounting for nearly 80% of total consumption, particularly in North African countries. This structural dependence not only undermines energy security but also exposes it to international price volatility and external shocks.

Within this heterogeneous regional context, Morocco has emerged as a leading actor in Africa's energy transition. In the absence of significant domestic fossil fuel resources, the country initiated a comprehensive reform of its energy policy in 2009 through the adoption of the National Energy Strategy. This strategy aims to raise the share of renewable energy to 52% of installed electricity generation capacity by 2030, as outlined by the Ministry of Energy Transition (2021). The reform seeks to diversify the national energy mix, enhance energy efficiency, and reduce dependence on energy imports. Moreover, this strategy orientation is consistent with Morocco's commitments, notably those undertaken during the twenty-second conference of the parties (COP22) held in Marrakesh (2016), as well as with the Sustainable Development Goals (SDGs), particularly emphasis goal 7, which focuses on ensuring access to affordable, reliable, and clean energy for all.

1. LITERATURE REVIEW AND HYPOTHESES

Since the 1970s, the causal relationship between energy consumption and economic growth has been a major field of empirical research, initially stimulated by oil crises and developments in energy transition policies. Within the framework of a neoclassical production model, energy is considered a key production factor alongside capital and labor, implying that higher energy consumption enhances productivity and economic performance.

In the European context, Narayan and Smyth (2008) examined the relationship between energy consumption and economic growth using time-series econometric techniques and found that energy consumption plays a significant role in promoting economic growth. Similarly, Štreimikienė and Kasperowicz (2016), employing panel data methods for European countries, showed that increased energy use positively affects economic growth. In an energy-dependent economy, Alshehry and Belloumi (2015) analyzed the relationship between energy consumption and economic growth in Saudi Arabia using cointegration and error correction models. Their results indicated that energy consumption has a positive and significant impact on economic growth in both the short and the long term. In a broader sample of oil-exporting countries, Damette and Seghir (2013) investigated the

energy-growth nexus using panel cointegration techniques and found that energy consumption contributes positively to economic growth. These empirical findings support the energy-led growth hypothesis, which emphasizes the crucial role of energy availability and reliability in fostering economic competitiveness and value creation.

However, empirical studies do not converge toward a single interpretation of the relationship between energy consumption and economic growth. A significant strand of the literature provides evidence of reverse causality, suggesting that economic growth precedes and drives energy consumption. From this perspective, increases in production, consumption, and trade activities generate higher energy demand. In the Chinese context, Zhang and Cheng (2009) examined the causal relationship between energy consumption and economic growth using cointegration and Granger causality tests. They found that economic growth leads to increased energy consumption. Similarly, in Malaysia, Azlina (2012) analyzed the energy-growth nexus using time-series econometric techniques and reported evidence supporting causality running from economic growth to energy consumption. To reconcile these divergent empirical findings, Payne (2010) proposed a classification framework that has become central in energy growth literature. This framework identifies four main hypotheses:

- (i) the growth hypothesis, which states that energy use promotes economic growth;
- (ii) the conservation hypothesis, which argues that economic growth leads to increased energy consumption;
- (iii) the feedback hypothesis, which defines a reciprocal causality between energy and economic growth; and finally
- (iv) the neutrality hypothesis, which indicates that there is no statistically relevant link between these two elements.

This analytical framework is widely adopted, as empirical results are found to be highly sensitive to country-specific characteristics, the periods considered, and the econometric methodologies employed, such as VAR, VECM, ARDL, NARDL, and heterogeneous panel models.

In this regard, empirical studies emphasize that the direction of causality between energy and growth remains fundamentally an empirical issue, largely dependent on productive structures, energy intensity, institutional framework, and the level of economic development. Alper and Oguz (2016) argue that these structural and institutional differences largely explain the heterogeneity of empirical results observed across countries and periods.

According to the growth hypothesis, energy is considered a productive input complementary to capital and labor, capable of stimulating economic activity both directly, through production, and indirectly, through investment, cost reduction, and improved competitiveness. This hypothesis is validated when causality tests, particularly those based on the Granger framework, reveal a unidirectional relationship running from energy consumption to economic growth. In this context, restrictive energy consumption policies may hinder economic growth, whereas increased investment in the energy sector can foster economic expansion. Several empirical studies support this hypothesis. Destek and Aslan (2017), Kahia et al. (2017a, 2017b), and Omri (2013) provided evidence of a causal relationship from energy consumption to economic growth across different

national and regional settings. However, the empirical evidence remains mixed. While some studies highlight favorable growth effects, others underline adverse impacts depending on energy mix, adjustment costs, and sectoral dynamics. In this regard, Awodumi and Adewuyi (2020), Pereira et al. (2021), and Alhashim et al. (2024) showed that the growth effects of energy consumption are highly sensitive to structural and technological conditions. Moreover, Bongers (2022) concludes that environmental impacts do not depend solely on the use of renewable energy, but also on the composition of the energy mix between renewable and non-renewable sources.

Conversely, the conservation hypothesis suggests that economic growth precedes energy consumption. Under this assumption, energy conservation or efficiency aimed at reducing energy use or waste is unlikely to harm economic performance since energy demand is mainly driven by economic growth. Empirical evidence supporting this hypothesis is provided by Abul et al. (2019), Aydın (2019), Vo et al. (2019), and Nasreen et al. (2020), who found causality running from economic growth to energy consumption. In such cases, any observed economic slowdown is more likely to stem from other structural constraints, such as governance issues, infrastructure deficiencies, trade openness, or institutional rigidities, rather than from direct restrictions on energy consumption, as emphasized by Almozaini (2020).

The feedback hypothesis, for its part, highlights a bidirectional and interdependent link between energy consumption and economic growth, whereby each stimulates the other. Numerous empirical studies, particularly those based on panel data techniques, support this hypothesis. Bildirici and Gokmenoglu (2017) and Rasoulinezhad and Saboori (2018) provided robust evidence of reciprocal causality. These findings suggest that energy policies should be carefully designed to improve energy efficiency while simultaneously sustaining economic growth.

Finally, the neutrality hypothesis argues that the consumption of energy represents too small a share of total production to exert a significant influence on economic development. Under this hypothesis, causality analyses reveal no meaning-

ful relationship between the variables, implying that energy-saving would not generate substantial macroeconomic effects. Empirical support for this hypothesis is provided by Apergis and Payne (2010a, 2010b), Belal et al. (2021), and Cengiz and Manga (2021).

The emergence of clean and renewable energy sources has profoundly reshaped this debate by integrating energy issues into the broader challenges of environmental sustainability and climate change mitigation. The global energy transition, driven by the gradual depletion of fossil fuels and international commitments to reduce emissions, has generated a growing body of empirical literature examining the relation between renewable energy consumption, economic growth, and environmental quality. Several studies draw on the environmental Kuznets curve hypothesis, which postulates that environmental degradation initially increases during early stages of development before declining beyond a certain income threshold. In the case of the United States, Menyah and Wolde-Rufael (2010) found a unidirectional causality running from economic growth to renewable energy consumption, suggesting that higher income levels stimulate investment in green energy. In contrast, for OECD countries, Apergis and Payne (2009) reported bidirectional causality, consistent with the principle of green growth.

Following the expansion of renewable energy and the acceleration of the energy transition, empirical studies examining the link between renewable energy and economic growth report results that largely mirror the traditional energy growth hypothesis identified in the literature. In particular, a positive effect supports the growth hypothesis, a negative or growth-containing effect reflects adjustment and transition cost, and statistical neutrality is consistent with the neutrality hypothesis.

On the one hand, numerous studies report a positive impact of renewable energy consumption on economic growth, particularly in developing countries, where investments in renewable energy stimulate employment, capital accumulation, and industrialization. Bhattacharya et al. (2016), Awodumi and Adewuyi (2020), and Wang et al. (2023) provided empirical evidence supporting this view. On the other hand, numerous studies

identify negative growth effects, often attributed to high adjustment costs, technological constraints, immaturity of renewable energy sectors, grid rigidity, and institutional weaknesses. Such findings are reported by Namahoro et al. (2021), Brini et al. (2017), and Bhattacharya et al. (2016). Finally, a third strand of literature supports the neutrality hypothesis, arguing that the share of renewable energy in the overall energy mix remains insufficient to significantly affect economic growth or to merely substitute for fossil energy. These conclusions are supported by Apergis and Payne (2010), Menegaki (2011), Keshavarzian and Tabatabaienasab (2021).

Beyond these mixed findings, recent studies increasingly highlight non-linear relationships and threshold effects. Ferhi and Helali (2024) and Dabboussi and Abid (2022) argue that renewable energy contributes to economic growth only after reaching a certain level of penetration, when economies of scale, infrastructure development, technological progress, and industrial learning reduce costs and enhance energy security. These results suggest that the macroeconomic impact of renewable energy depends less on its initial adoption than on its effective integration into the production system.

Concerning Morocco, the empirical literature mainly focuses on the relationship between economic growth, energy diversification, and carbon dioxide emissions (CO₂), often within a framework of the environmental Kuznets curve. Saidi and Hammami (2020) showed that beyond a certain income threshold, CO₂ emissions tend to decline due to energy diversification and expansion of renewable energy sources. However, direct analysis of the link between renewable energy consumption and economic growth remains relatively limited. Nevertheless, several studies emphasize the positive effects of large-scale renewable energy investments, such as the Noor Ouarzazate solar complex and the Tarfaya wind farm, on energy security and economic efficiency. Bouoiyour et al. (2019) and Charfeddine and Kahia (2019) provided empirical evidence supporting this view. Using the ARDL model, Ech-Choudany and Hafid (2023) identified a unidirectional causality running from renewable energy consumption to economic growth, thereby validating the growth

hypothesis. Similarly, Aguilal et al. (2025) confirmed that renewable energy constitutes a significant driver of Morocco's economic development, suggesting that the macroeconomic benefits of the energy transition are likely to materialize mainly in the long term. These results underscore that the economic advantages of the energy transition may outweigh its immediate environmental impacts, and emphasize the importance of improving government policies, particularly regarding energy infrastructure, governance, storage capacity, and the industrialization of renewable energy value chains.

Within this context, and given the varied results observed worldwide, this study seeks to examine the nature of the relationship between the use of renewable energy and economic growth in Morocco. To this end, the following hypotheses are formulated:

H1: The growth hypothesis; energy consumption drives economic growth.

H2: The conservation hypothesis; economic growth leads to increased energy consumption.

H3: The feedback hypothesis; there is a bidirectional causal relationship between energy consumption and economic growth.

H4: The neutrality hypothesis; there is no statistically significant relationship between the two variables.

2. METHODOLOGY

2.1. Data source

The analysis is based on annual macroeconomic data covering the period 1990–2024, collected from the World Development Indicators (WDI) database and Our World in Data (OWID). This choice is motivated by the availability, reliability, and international comparability of the statistical series provided by these sources.

The model incorporates the following variables. GDP (LGDP) is expressed in logarithmic form

and measured in the current local currency, serving as a proxy for economic growth (the dependent variable). The logarithmic transformation is employed to stabilize variance, reduce scale effects, and facilitate economic interpretation in terms of relative changes. Renewable energy consumption (RE) is measured as a share of total primary energy consumption. Trade openness (TO) is expressed as a percentage of GDP. Carbon dioxide (CO₂) emissions per capita are measured in metric tons to capture the environmental dimension associated with economic performance. All variables were converted to natural logarithms, which helps to reduce dispersion, balance variance, and allows the interpretation of estimated coefficients as elasticities.

2.2. Econometric model

This study investigates the relationship between economic growth, the usage of renewable energy, and CO₂ emissions using the ARDL (Autoregressive Distributed Lag Model) created by Pesaran et al. (2001). This dynamic model is perfectly suited to time series with mixed integration orders, i.e., when certain variables are stationary at the level while other variables are stationary at first difference I(1).

The main strength of the ARDL method is its capacity to jointly assess the short and long-term links between the variables, while taking into account their time lags. In addition, it is suitable for small samples, such as that of Morocco, making it a flexible and robust econometric method. The ARDL representation is as follows:

$$LGDP = \alpha + \beta_1 \cdot RE + \beta_2 \cdot TO + \beta_3 \cdot CO_2 + \varepsilon_t, \quad (1)$$

where β_1 , β_2 , β_3 are the multipliers for the variables RE , TO , CO_2 , respectively. ε is the error term.

2.3. Estimation procedure

The empirical relationships are estimated within the autoregressive distributed lag (ARDL) modeling framework. The estimation procedure follows a sequence of well-defined steps. First, the order of integration of each variable is examined to ensure that none is integrated of order two, I(2). To this

end, the Augmented Dickey–Fuller (ADF) unit root test is employed to determine whether the variables are stationary in levels or in first differences. Second, the bounds testing approach proposed by Pesaran et al. (2001) is applied to assess the existence of a long-run cointegration relationship among the variables. This approach is particularly suitable in the presence of a mixture of I(0) and I(1) variables and allows for the simultaneous estimation of short- and long-run dynamics.

3. RESULTS AND DISCUSSION

Prior to conducting cointegration analysis using the ARDL model, several preliminary steps must be undertaken to guarantee the robustness and reliability of the results.

3.1. Stationarity and unit root tests

Table 1. Stationarity tests of the series

Variables	LGDP	RE	TO	CO2
At level				
t-Statistic	-2.3412	-4.0405	-0.6946	-1.0400
Prob.	0.1626	0.0024	0.8403	0.7324
At first difference				
t-Statistic	-4.0513	-7.9469	-7.5445	-10.0093
Prob.	0.0022	0.0000	0.0000	0.0000
Order of integration	I(1)	I(0)	I(1)	I(1)

In this study, we use the Augmented Dickey-Fuller (ADF) test. The results of the ADF unit root test for the variables are presented in Table 1. We observe that the variables are not equally stationary. Three variables (LGDP, TO, and CO2) are stationary at the first difference, and one variable (RE) is stationary at the level I(0). Therefore, the study of the stationarity of time series at different levels (0 or 1) is compatible with the adoption of the ARDL model.

Table 2. Bounds test

Test Statistic	Value					
F-statistic	7.6565					
level	10%		5%		1%	
Sample Size	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
30	2.676	3.586	3.272	4.306	4.614	5.966
35	2.618	3.532	3.164	4.194	4.428	5.816
Asymptotic	2.37	3.2	2.79	3.67	3.65	4.66

Note: * I(0) and I(1) are respectively the stationary and non-stationary bounds.

3.2. ARDL model estimation

After verifying cointegration and the significance of Fisher’s statistic, the ARDL model is estimated. The coefficient of determination ($R^2 = 0.998036$) shows that the model contains robust variables and that 99.8036% of these exogenous variables explain the endogenous variable, while the remaining less than 1% is explained by factors that were not taken into account in this model.

After estimating the model, we move on to the next step, which consists of determining whether there is a long-term relationship between the variables taken into consideration. We use the ARDL Bounds test to determine whether a long-term relationship exists. Table 2 demonstrates that Fisher’s statistic ($F = 7.6566$) is higher than the critical value interval’s upper bound across all significance levels. This result validates our series cointegration.

3.3. Assumption violations, diagnostics, and stability tests

To ensure the robustness and credibility of the ARDL model results, a series of diagnostic tests is conducted. The residual diagnostic results reported in Table 3 indicate that the estimated model is free of major econometric problems, including non-normality, serial correlation, and heteroscedasticity, as the corresponding null hypotheses cannot be rejected. These outcomes suggest that the ARDL estimates are statistically reliable and not subject to spurious regression.

In addition, the stability of the estimated coefficients is assessed using recursive stability tests. Figures 1 and 2 present the CUSUM and CUSUM of Squares (CUSUMSQ) tests, respectively. The re-

Table 3. Residual diagnostic test results

Residual diagnostic tests	Decision rule	Probability value	Decision Accept
Breusch–Godfrey Serial Correlation LM Test	H0: No serial correlation ($p > 0.05$) H1: Serial correlation ($p < 0.05$)	0.6633*	Accept the null hypothesis of no serial correlation
Breusch–Godfrey Heteroscedasticity Test	H0: Homoscedasticity ($p > 0.05$) H1: Heteroscedasticity ($p < 0.05$)	0.3054*	Accept the null hypothesis of homoscedasticity
Normality Test	H0: Residual terms are normally distributed ($p > 0.05$) H1: Residual terms are not normally distributed ($p < 0.05$)	0.062885*	Accept the null hypothesis of normal distribution

Note: (*) Acceptance of null hypothesis at 1%, 5%, or 10% significance level.

sults indicate that the model parameters remain stable over the sample period, further supporting the consistency and reliability of the estimated ARDL specification.

3.4. Discussion of the short- and long-run coefficients

Table 4 shows that in the short term, the neutrality of renewable energy consumption on Morocco’s GDP means that a one-off increase in renewables does not immediately translate into a measurable

change in economic activity. This result can be explained by the fact that the economic benefits of renewables are mainly achieved through gradual mechanisms (investment, infrastructure, productivity gains, energy competitiveness, and reduced import bills), whose effects take time to materialize. Thus, renewables do not act as an instant economic lever, but rather as a growth factor with a delayed impact, which is observable in the long term.

Table 5 presents the estimated elasticities, or long-term coefficients. The results show that a positive

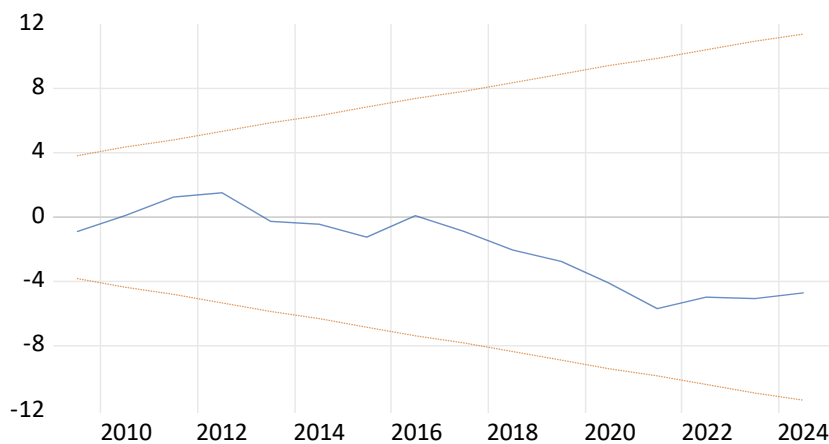


Figure 1. CUSUM test

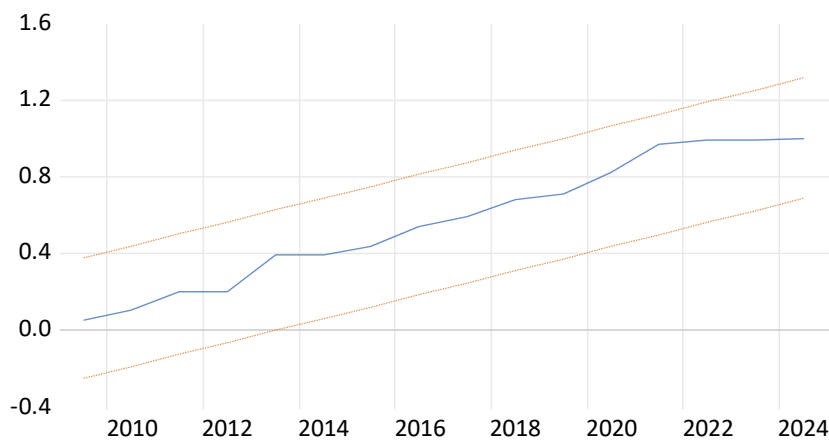


Figure 2. CUSUM test of squares

Table 4. The short-run coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
COINTEQ*	-0.2909	0.0421	-6.9176	0.0000
D(LGDP(-1))	-0.4587	0.1533	-2.9916	0.0072
D(LGDP(-2))	-0.4711	0.1356	-3.4731	0.0024
D(RE)	0.0059	0.0046	1.2991	0.2087
D(RE(-1))	-0.0007	0.0051	-0.1412	0.8891
D(RE(-2))	0.0232	0.0045	5.1533	0.0000
D(RE(-3))	0.0069	0.0054	1.2647	0.2205
D(TO)	0.0045	0.0018	2.5322	0.0198
D(TO(-1))	0.0076	0.0016	4.6170	0.0002
D(TO(-2))	0.0085	0.0020	4.1667	0.0005
D(TO(-3))	0.0090	0.0029	3.0574	0.0062
D(CO2)	0.0453	0.0846	0.5356	0.5982
D(CO2(-1))	-0.7036	0.1050	-6.7011	0.0000
D(CO2(-2))	-0.4848	0.1368	-3.5424	0.0020
D(CO2(-3))	-0.3402	0.1336	-2.5458	0.0192

Table 5. The long-run coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RE	0.0456	0.0212	-2.1507	0.0394
TO	0.0025	0.0124	0.2007	0.8422
CO2	0.9453	0.3189	2.9639	0.0058
C	9.0274	0.3839	23.5156	0.0000

coefficient is associated with renewable energy consumption, confirming that, in Morocco's case, the energy transition is not limited to an environmental objective, but is fully in line with a long-term economic development strategy. The growth hypothesis is therefore fully verified in the long term, indicating that renewable energy acts as a strategic productive factor, on a par with capital or labor, in the dynamics of Moroccan GDP growth.

Economically speaking, this result suggests that renewable energy consumption is a real driver of long-term economic growth in Morocco. Increased renewable energy consumption contributes to GDP growth through several structural channels.

Firstly, the development of renewable energies promotes the growth of energy supply at a lower marginal cost, reducing dependence on fossil fuel imports and improving the energy trade balance. Secondly, massive investment in renewable energy projects (solar, wind, hydro) stimulates productive investment, the creation of skilled jobs, and the development of an industrial base and related services (construction, engineering, maintenance).

Thirdly, the availability of more stable and competitive energy improves overall factor productivity, particularly in the industrial and service sectors, thereby strengthening the Moroccan economy's capacity to sustain sustainable growth.

In light of the empirical findings, hypothesis H1 is supported. The results largely corroborate the green growth theory, which posits that the integration of renewable energy constitutes a driver of sustainable economic development. Forecasts derived from an ARDL model indicate that renewable energy exerts a positive and significant impact on long-term economic growth, although this effect remains limited in the short term. This temporal pattern is consistent with the findings of Pereira et al. (2021), who emphasize that the growth-enhancing effects of green technologies intensify gradually through infrastructure accumulation, technological innovation, and institutional adjustment.

In the Moroccan context, the application of the ARDL framework reveals a unidirectional causal relationship running from renewable energy consumption to economic growth. This result provides strong support for the growth hypothesis,

which argues that energy transition acts as a fundamental engine of economic development in industrializing economies.

However, the empirical results do not provide clear evidence of a causal relationship between the share of renewable energy consumption and carbon dioxide (CO₂) emissions. In the Moroccan context, the absence of a statistical link can be explained by several structural factors. First, fossil fuels continue to dominate electricity generation, accounting for more than 60% of total production. Second, although renewable energy capacity has expanded rapidly in recent years, its share in the overall energy mix remains insufficient to exert a substantial impact on national emissions levels. Third, the sustained growth in total demand tends to offset the potential environmental benefits associated with the deployment of renewable energy. These findings are partially consistent with those reported by Bongers (2022), who emphasized that the environmental effects of renewable energy critically depend on the composition of the energy mix, the regulatory framework, and the level of technological maturity of green energy systems.

Finally, some methodological limitations should be acknowledged. The ARDL model relies on time series data that may be relatively short and subject to structural breaks associated with changes in national energy policies. Moreover, certain explanatory variables, such as institutional quality and research and development expenditure, could not be fully incorporated into the model. These limitations highlight the need for future research employing non-linear econometric techniques, threshold models, or sectoral analyses in order to more accurately capture the complex interaction between renewable energy, economic growth, and environmental outcomes.

Overall, Morocco's experience illustrates an energy transition primarily oriented toward economic development, while its environmental effects remain to be consolidated. The economic benefits of renewable energy can be further strengthened through a combination of ambitious energy policies, technological innovations, and institutional reforms, ensuring that economic development proceeds in a manner consistent with long-term ecological sustainability.

CONCLUSION

The objective of this study is to examine the existence and nature of the relationship between renewable energy consumption and economic growth in Morocco. To achieve this objective, the analysis employs an Autoregressive Distributed Lag (ARDL) model, which allows for the simultaneous identification of short-term dynamics and long-term equilibrium between the variables.

The empirical results reveal the presence of a unidirectional causal relationship between economic growth and energy consumption, thereby supporting the growth hypothesis. This finding suggests that the development of renewable energy sources constitutes a long-term economic lever for economic growth. However, the relatively limited share of renewable energy in Morocco's energy mix constrains the expected environmental benefits, while the continued reliance on fossil fuels contributes to persistently high levels of emissions. In addition, the results indicate a positive and statistically significant effect of trade opening with time lags, implying that the gains from trade do not materialize immediately. From an economic perspective, this dynamic can be explained by the fact that increased trade initially stimulates demand, business activity, and investment before progressively enhancing productivity through the adoption of more advanced technologies and inputs, knowledge diffusion, and intensified competition.

From an academic standpoint, further research could extend this study by incorporating institutional and environmental variables in order to explore more deeply the causal relation between renewable energy consumption and economic growth. Moreover, the use of non-linear econometric approaches could help capture the potential threshold effects specific to Morocco's economic structure.

Overall, this paper contributes to a better understanding of the role of renewable energy as a catalyst for sustainable economic growth in Morocco. It underscores the importance of a coherent and integrated energy policy, based on innovation, diversification, and sustainability, as a key component in ensuring long-term economic resilience and environmentally responsible development.

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REFERENCES

- Abul, S. J., Satrovic, E., & Muslija, A. (2019). The link between energy consumption and economic growth in Gulf Cooperation Council countries. *International Journal of Energy Economics and Policy*, 9(5), 38-45. <https://doi.org/10.32479/ijeeep.7872>
- African Development Bank. (2022). *African Economic Outlook 2022*. Retrieved from <https://www.afdb.org/en/documents/african-economic-outlook-2022>
- Aguilal, A., Hennach, M., Outtaj, B., & Ech-Choudany, R. (2025). Empirical analysis of the relationship between renewable energy consumption and long-term economic growth in Morocco. *Environmental Economics*, 16(4), 154-165. [https://doi.org/10.21511/ee.16\(4\).2025.10](https://doi.org/10.21511/ee.16(4).2025.10)
- Alhashim, M., Rehman, M. Z., Ansari, S., & Ahmed, P. (2024). Examining the influence of renewable energy consumption, technological innovation, and export diversification on economic growth: Empirical insights from E-7 nations. *Sustainability*, 16(21). <https://doi.org/10.3390/su16219159>
- Almozaini, M. S. (2020). The dynamic effects of renewable energy on economic growth: The case of China. *Energy Studies Review*, 24(1). <https://doi.org/10.15173/esr.v24i1.4293>
- Alper, A., & Oguz, O. (2016). The role of renewable energy consumption in economic growth: Evidence from asymmetric causality. *Renewable and Sustainable Energy Reviews*, 60, 953-959. <https://doi.org/10.1016/j.rser.2016.01.123>
- Alshehry, A. S., & Belloumi, M. (2015). Energy consumption, carbon dioxide emissions and economic growth: The case of Saudi Arabia. *Renewable and Sustainable Energy Reviews*, 41, 237-247. <https://doi.org/10.1016/j.rser.2014.08.004>
- Apergis, N., & Payne, J. E. (2009). Energy consumption and economic growth: Evidence from the Commonwealth of Independent States. *Energy Economics*, 31(5), 641-647. <https://doi.org/10.1016/j.eneco.2009.01.011>
- Apergis, N., & Payne, J. E. (2010a). Energy consumption and growth in South America: Evidence from a panel error correction model. *Energy Economics*, 32(6), 1421-1426. <https://doi.org/10.1016/j.eneco.2010.04.006>
- Apergis, N., & Payne, J. E. (2010b). The emissions, energy consumption, and growth nexus: Evidence from the Commonwealth of Independent States. *Energy Policy*, 38(1), 650-655. <https://doi.org/10.1016/j.enpol.2009.08.029>
- Awodumi, O. B., & Adewuyi, A. O. (2020). The role of non-renewable energy consumption in economic growth and carbon emissions: Evidence from oil producing economies in Africa. *Energy Strategy Reviews*, 27, Article 100434. <https://doi.org/10.1016/j.esr.2019.100434>
- Aydin, M. (2019). Renewable and non-renewable electricity consumption-economic growth nexus: Evidence from OECD countries. *Renewable Energy*, 136, 599-606. <https://doi.org/10.1016/j.renene.2019.01.008>

13. Azlina, A. A. (2012). Energy consumption and economic development in Malaysia: A multivariate cointegration analysis. *Procedia – Social and Behavioral Sciences*, 65, 674-681. <https://doi.org/10.1016/j.sbspro.2012.11.183>
14. Belal, I. A. M., Ahmed, S. A. K., & Boujedra, F. H. (2021). The causal relationship between electricity consumption and economic growth in the Kingdom of Saudi Arabia: A dynamic causality test. *International Journal of Energy Economics and Policy*, 11(1), 333-340. <https://doi.org/10.32479/ijeep.10488>
15. Bhattacharya, M., Paramati, S. R., Ozturk, I., & Bhattacharya, S. (2016). The effect of renewable energy consumption on economic growth: Evidence from top 38 countries. *Applied Energy*, 162, 733-741. <https://doi.org/10.1016/j.apenergy.2015.10.104>
16. Bildirici, M. E., & Gökmenoğlu, S. M. (2017). Environmental pollution, hydropower energy consumption and economic growth: Evidence from G7 countries. *Renewable and Sustainable Energy Reviews*, 75, 68-85. <https://doi.org/10.1016/j.rser.2016.10.052>
17. Bongers, A. (2022). Energy mix, technological change, and the environment. *Environmental Economics and Policy Studies*, 24, 341-364. <https://doi.org/10.1007/s10018-021-00324-8>
18. Bouoiyour, J., Selmi, R., Hammoudeh, S., & Wohar, M. E. (2019). What are the categories of geopolitical risks that could drive oil prices higher? Acts or threats? *Energy Economics*, 84, Article 104523. <https://doi.org/10.1016/j.eneco.2019.104523>
19. Brini, R., Amara, M., & Jemmali, H. (2017). Renewable energy consumption, international trade, oil price and economic growth inter-linkages: The case of Tunisia. *Renewable and Sustainable Energy Reviews*, 76, 620-627. <https://doi.org/10.1016/j.rser.2017.03.067>
20. Cengiz, O., & Manga, M. (2021). The causal linkages between renewable energy consumption, economic growth, oil prices and CO₂ emissions in selected OECD countries. *Journal of Productivity*, 3, 165-183. <https://doi.org/10.51551/verimlilik.707804>
21. Charfeddine, L., & Kahia, M. (2019). Impact of renewable energy consumption and financial development on CO₂ emissions and economic growth in the MENA region: A panel vector autoregressive (PVAR) analysis. *Renewable Energy*, 139, 198-213. <https://doi.org/10.1016/j.renene.2019.01.010>
22. Dabboussi, M., & Abid, M. (2022). A comparative study of sectoral renewable energy consumption and GDP in the U.S.: Evidence from a threshold approach. *Renewable Energy*, 192, 705-715. <https://doi.org/10.1016/j.renene.2022.03.057>
23. Damette, O., & Seghir, M. (2013). Energy as a driver of growth in oil exporting countries? *Energy Economics*, 37, 193-199. <https://doi.org/10.1016/j.eneco.2012.12.011>
24. Destek, M. A., & Aslan, A. (2017). Renewable and non-renewable energy consumption and economic growth in emerging economies: Evidence from bootstrap panel causality. *Renewable Energy*, 111, 757-763. <https://doi.org/10.1016/j.renene.2017.05.008>
25. Ech-Choudany, R., & Hafid, H. (2023). La transition énergétique entre croissance économique et préservation écologique: Une analyse empirique de la courbe environnementale de Kuznets au Maroc [Energy transition between economic growth and ecological preservation: An empirical analysis of the Environmental Kuznets Curve in Morocco]. *International Journal of Accounting, Finance, Auditing, Management and Economics*, 4(4-2), 123-140. (In French). <https://doi.org/10.5281/zenodo.8245039>
26. Ferhi, A., & Helali, K. (2024). The impact of renewable energy on the environment and socio-economic welfare: Empirical evidence from OECD countries. *Journal of the Knowledge Economy*, 15(1), 4776-4799. <https://doi.org/10.1007/s13132-023-01320-x>
27. Kahia, M., Aïssa, M. S. B., & Lanouar, C. (2017a). Renewable and non-renewable energy use-economic growth nexus: The case of MENA net oil importing countries. *Renewable and Sustainable Energy Reviews*, 71, 127-140. <https://doi.org/10.1016/j.rser.2017.01.010>
28. Kahia, M., Kadria, M., Aïssa, M. S.B., & Lanouar, C. (2017b). Modelling the treatment effect of renewable energy policies on economic growth: Evaluation from MENA countries. *Journal of Cleaner Production*, 149, 845-855. <https://doi.org/10.1016/j.jclepro.2017.02.030>
29. Keshavarzian, M., & Tabatabaïenasab, M. (2021). Application of bootstrap panel Granger causality test in determining the relationship between renewable and non-renewable energy consumption and economic growth: A case study of OPEC countries. *Technology and Economics of Smart Grids and Sustainable Energy*, 6, Article 10. <https://doi.org/10.1007/s40866-021-00106-X>
30. Menegaki, A. N. (2011). Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis. *Energy Economics*, 33(2), 257-263. <https://doi.org/10.1016/j.eneco.2010.10.004>
31. Menyah, K., & Wolde-Rufael, Y. (2010). CO₂ emissions, nuclear energy, renewable energy and economic growth in the US. *Energy Policy*, 38(6), 2911-2915. <https://doi.org/10.1016/j.enpol.2010.01.024>
32. Ministry of Energy Transition and Sustainable Development. (2021). *National Energy Strategy of Morocco*. Rabat, Morocco.
33. Namahoro, J. P., Wu, Q., Xiao, H., & Zhou, N. (2021). The asymmetric nexus of renewable energy consumption and economic growth: New evidence from Rwanda. *Renewable Energy*, 174, 336-346. <https://doi.org/10.1016/j.renene.2021.04.017>
34. Narayan, P. K., & Smyth, R. (2008). Energy consumption and real GDP in G7 countries: New evidence from panel cointegration with structural breaks. *Energy*

- Economics*, 30(5), 2331-2341. <https://doi.org/10.1016/j.eneco.2007.10.006>
35. Nasreen, S., Mbarek, M. B., & Atiq-ur-Rehman, M. (2020). Long-run causal relationship between economic growth, transport energy consumption and environmental quality in Asian countries: Evidence from heterogeneous panel methods. *Energy*, 192, Article 116628. <https://doi.org/10.1016/j.energy.2019.116628>
 36. Omri, A. (2013). CO₂ emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models. *Energy Economics*, 40, 657-664. <https://doi.org/10.1016/j.eneco.2013.09.003>
 37. Payne, J. E. (2010). Survey of the international evidence on the causal relationship between energy consumption and economic growth. *Journal of Economic Studies*, 37(1), 53-95. <https://doi.org/10.1108/01443581011012261>
 38. Pereira, R., Sequeira, T., & Cerqueira, P. (2021). Renewable energy consumption and economic growth: A note reassessing panel data results. *Environmental Science and Pollution Research*, 28, 19511-19520. <https://doi.org/10.1007/s11356-021-12961-3>
 39. Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289-326. <https://doi.org/10.1002/jae.616>
 40. Rasoulinezhad, E., & Saboori, B. (2018). Panel estimation for renewable and non-renewable energy consumption, economic growth, CO₂ emissions, the composite trade intensity, and financial openness of the Commonwealth of Independent States. *Environmental Science and Pollution Research*, 25, 17354-17370. <https://doi.org/10.1007/s11356-018-1827-3>
 41. Saidi, K., & Hammami, S. (2015). The impact of energy consumption and CO₂ emissions on economic growth: Fresh evidence from dynamic simultaneous-equations models. *Sustainable Cities and Society*. <https://doi.org/10.1016/j.scs.2014.05.004>
 42. Štreimikienė, D., & Kasperowicz, R. (2016). Review of economic growth and energy consumption: A panel cointegration analysis for EU countries. *Renewable and Sustainable Energy Reviews*, 59, 1545-1549. <https://doi.org/10.1016/j.rser.2016.01.041>
 43. Vo, A. T., Vo, D. H., & Le, Q. T. (2019). CO₂ emissions, energy consumption, and economic growth: New evidence in the ASEAN countries. *Journal of Risk and Financial Management*, 12(3). <https://doi.org/10.3390/jrfm12030145>
 44. Wang, L., Ali, A., Ji, H., Chen, J., & Ni, G. (2023). Links between renewable and non-renewable energy consumption, economic growth, and climate change: Evidence from five emerging Asian countries. *Environmental Science and Pollution Research*, 30, 83687-83701. <https://doi.org/10.1007/s11356-023-27957-4>
 45. Zhang, X. P., & Cheng, X. M. (2009). Energy consumption, carbon emissions, and economic growth in China. *Ecological Economics*, 68(10), 2706-2712. <https://doi.org/10.1016/j.ecolecon.2009.05.011>