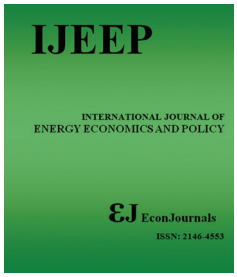

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The Moroccan Evidence through an ARDL Approach to the Education, Renewable Energy Consumption, and Economic Growth Nexus

Yahya Fikri*

National School of Business and Management, Tangier 90000 (ENCG - TANGER), Research Laboratory in Governance and Performance of Organizations (LRGPO), Research Team (ERGOS): Governance, Organizations and Societies, Abdelmalek Essaadi University Tetouan, 93000, Morocco. *Email: fikriyahya685@gmail.com

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ABSTRACT

Education is a key component of sustainable development since it influences economic growth, the energy transition, and environmental behaviors. In the Moroccan context, the increase in the rate of solarization reflects public initiatives around education, with potential benefits for productivity and technological innovation. The current study aims to determine Morocco's impact on CO_2 emissions, renewable energy consumption (REC), education, general government consumption spending (GGCS), and economic growth (EG). This study used an autoregressive methodology for stationarity and distributed degradation in conjunction with the least squares ordinary approach to evaluate the short- and long-term correlations between the model's variables. For the study, World Development Indicators (WDI) annual data for the years 1993 through 2020 has been collected. The bound test was employed to assess long-term relationships, while the White test was used to check for heteroscedasticity in model residuals. The empirical research demonstrated numerous relationships between the independent and dependent variables. The actual data showed that although all independent variables were not stationary in the first difference, they became stationary in the second difference, while the dependent variable was stationary in the first difference. The model simulation using the bound test confirmed a long-term relationship between the independent and dependent variables. However, the long- and short-term relationships between EG and education were disproved. The model residuals exhibited no signs of heteroscedasticity. The findings highlight the complex interplay between education, CO_2 emissions, renewable energy consumption, government spending, and economic growth in Morocco. Policymakers should consider these relationships when designing strategies for sustainable development, particularly in balancing economic expansion with environmental sustainability and education development.

Keywords: Education, Dioxide Carbon Emissions, Renewable Energy Consumption, Economic Growth, ARDL Approach, Human Capital, Morocco
JEL Classifications: E21, E61, E66, E42

1. INTRODUCTION

Contrary to conventional theory, which holds that only labor and capital factors contribute to the evolution of economic growth at different levels across economies, modern theory of education emphasizes that not only these factors contribute, but also the quality of the labor factor itself is a crucial factor influencing economic growth. EG and human funds have longsighted grabbed the curiosity of academics and politicians. The notion of "human capital," which is sometimes applied interchangeably with "human resources," designates the multiplicity of talents, experiences, capacities, and knowledge that human being influences to the workstation (Anaduaka, 2014).

The aim of human capital in advancing EG has raised as wealth lift from usual industries to knowledge-based sectors (Begum

et al., 2015). New growth models that support the emphasis on education and its significance for a countries' economic performance have been developed because of several - though not always evident - relationships between human capital and an economy's potential for innovation and productivity growth (Bouyghrissi et al., 2021).

An educated workforce can promote productivity and innovation, both of which will support EG Cameron and Trivedi (2005). A fundamental idea in economics, EG refers to the steady increase in a nation's output of commodities and services over time. Human development, employment, and per capita income are further measures of economic advancement (Chen et al., 2020). Scholars and decision-makers have long been interested in the relationship among EG and human capital (Devassia et al., 2024). Climate change and its impact on the environment are currently among the most pressing problems facing our planet (Fikri and Rhalma, 2024). Studies and empirical research have demonstrated an inconsistent relationship between GGCS, REC, CO_2 emissions, and EG sustainability (Haji, 2011).

Still, in order to create a strong foundation for long-term economic growth and innovation, domestic investment is needed. The need for more government spending has been emphasized by economic theories like Big Push theory and Keynesian demand to improve public goods and, as a result, improve economic well-being in an economy (Hanadi, 2024). The main forces behind economic growth, according to Solow's growth paradigm (Howitt and Aghion, 1998). Plus, Morocco is not unaware that climate change is turning into a significant worldwide issue. Morocco is one of the countries that is now working on short- and medium-term programs to develop renewable energy.

The current study intends to investigate the relationship between Morocco's economic performance, the percentage of GDP that public administrations spend on final consumption, the quantity of dioxide carbon emissions per resident, and the share of renewable energy sources in total energy consumption. His intention is to offer a novel perspective on these connections, especially considering Moroccan culture.

The connection between REC, EG, GGCS, and carbon dioxide emissions has received a lot of attention in the economic literature. The literature has examined the usage of renewable energy sources, public spending, and CO_2 emissions. Examining the association among Morocco's CO_2 emissions, REC, EDUCATION, GGCS, and EG between 1993 and 2020 is the aim of the current study. Based on past empirical research conducted in the Moroccan setting, we have chosen and integrated our components (Anaduaka, 2014). Education is a key component of sustainable development since it influences economic growth, the energy transition, and environmental behaviors.

In the Moroccan context, the increase in the rate of solarization reflects public initiatives around education, with potential benefits for productivity and technological innovation.

The current study aims to determine Morocco's impact on CO_2 emissions, REC, education, GGCS, and EG. Also, there is no documented study found the relationship between education, renewable energy consumption, and economic growth in the Moroccan context.

This study is an effort to address this gap. This study contributes to the existing literature by examining the unique dynamics of education, renewable energy consumption, and economic growth within the Moroccan context. It provides empirical evidence on the long-term relationships between these variables while challenging some conventional assumptions, such as the direct short-term impact of education on economic growth.

The use of autoregressive and cointegration techniques adds robustness to the analysis, offering valuable insights for both academic research and Policymakers. Our problem is as follows: What's the link between Education, CO_2, REC, GGCS and EG? For Moroccan officials, this is crucial because it allows them to create policies for sustainable growth that balance economic advancement with environmental preservation. The outline of this essay is as follows ahead of time: (1) A review of the literature is given. (2) A description of the models, estimation methods, and data sources is given. (3) Displays the pertinent portion. (4) Gives a summary of the conclusions and recommendations.

2. LITERATURE REVIEW

It became imperative to evaluate the development model and include education as a component influencing EG. This led to the creation of the modern theory of human capital in the 1960s. This hypothesis is predicated on the notion that a modern educational system emphasizing the sciences, innovation, and technology, along with an accessible healthcare system that permits the reproduction of these physical qualities, are necessary components of a quality work factor (Joachim, 2021). Theodor Schultz and Gary Backer, two University of Chicago economists, stress the value of education in creating human capital capable of achieving national productivity.

Schultz defines training as encompassing all the competencies, know-how, and skills required to boost employee productivity in the workplace. Keynes (1936) asserted that the duration of education at a university or college determines salary disparities between workers and individuals. A person's degree must allow them to work more productively and earn more money; in this sense, it is critical to ascertain the reasonable evaluation of the advantages and disadvantages of the duration of their study and training period in relation to the returns on investment (Joachim, 2021).

The results relate to a micro analysis; on the other hand, at the macro level, training and education expenditures directly raise the productivity of the national economy. This, in turn, attracts lead to the specialization of skilled labor in high-value added industries centered on innovation and technology according to Kripfganz and Schneider (2020). The body of research on economics has unequivocally demonstrated that human capital influences a nation's capacity for economic growth.

According to Meltzer (1981) referenced Mincer (1958) for their study on the returns on education, which demonstrated a positive

and consistent relationship between production and educational attainment in a variety of businesses and nations. By emphasizing a favorable correlation between economic performance and human resource development in their research on African countries like Nigeria, Pedroni (2004) illustrated how human resources propel EG in developing countries.

Morocco has committed itself to attaining objectives meant to produce swift economic expansion and improve the standard of living for its citizens ever since it gained independence (Anaduaka, 2014). According to Pesaran et al. (2001) citation of Keynes' EG theories, public spending can be considered as an example of an externality that promotes equitable growth. Because government expenditure promotes sustainable development, it has been demonstrated to be the primary source of aggregate demand.

In this context, Howitt and Aghion (1998) highlighted that labor, capital, and technological innovation are the three primary drivers of EG and that these drivers are all linked to the use of energy as the primary means of production. The examination revealed empirical discrepancies in the connections among government expenditure, energy use, economic expansion, and carbon dioxide emissions.

The current investigation's theoretical framework was constructed using Keynes's EG method (Pesaran et al. 2001). According to Psacharopoulos and Patrinos (2018) rising government spending accelerates the expansion of production. It is evident that there are several causal pathways between GGCS and EG (Raihan, and Voumik, 2022; Anaduaka, 2014). In the case of green energy, however, the relationship between GGCS and EG was more varied. Solow (1956) examined the rise in public research funding, energy efficiency, and the expansion of the green economy from 2008 to 2021.

According to their results, public support for R&D and human resources is essential for maintaining a green economy through technology-driven industrial processes that offer various benefits. Energy use is a major factor in hastening environmental degradation, according to a number of studies Raihan and Voumik (2022). Subsequent studies, such as their demonstrated a causal relationship between GDP development (growth) and CO_2. The relationship between GDP per capita and the LR co-integration between energy use and the Chinese population in the real provinces was examined by (Raihan and Voumik, 2022; Anaduaka 2014).

It was found that there was an effective cointegrated association that remained strong. Taher (2017) noted changing relationships among GDP growth, energy use, population increase, and carbon dioxide emissions. The results show that Malaysia's national carbon dioxide output per person is positively impacted by both GDP per capita and energy usage. Regarding the conclusions reached by Stock and Watson (1993), there is a significant and positive correlation between CO_2 emissions and EG. It has been shown that energy use alone can gradually lower CO_2 emissions.

On the other hand, Yule (1926) examined the relationship between EG and REC in a sample of 103 countries using the model threshold. The results showed that using renewable energy only serves to accelerate EG after a certain point is reached. For nations like Lebanon to prosper socially and economically, renewable energy investments are essential. Zhang et al. (2021) found that there was a positive correlation between the use of REC and EG in Lebanon between 1990 and 2012.

Regarding the conclusions reached by Stock and Watson (1993), there is a significant and positive correlation between CO_2 emissions and EG. It has been shown that energy use alone can gradually lower CO_2. Morocco's economic climate has greatly improved due to recent legal changes. The main goals of these changes have been to boost investment opportunities and enhance the business environment across a wide range of.

On the other hand, Yule (1926) examined the association among EG and REC in a sample of 103 countries using the model threshold. The results showed that using renewable energy only serves to accelerate EG after a certain point is reached. For nations like Lebanon to prosper socially and economically, renewable energy investments are essential. Zhang et al. (2021) found that there was a positive correlation between the use of REC and EG in Lebanon between 1990 and 2012.

In summary, the literature review suggests that there may be a relationship between EG, education, and REC. Furthermore, due to a lack of studies examining this relationship, the Moroccan context does not include these three variables for the interval (1990–2020).

This study contributes to the existing literature by examining the unique dynamics of education, energy transition, and economic growth within the Moroccan context. It provides empirical evidence on the long-term relationships between these variables while challenging some conventional assumptions, such as the direct short-term impact of education on economic growth. The use of autoregressive and cointegration techniques adds robustness to the analysis, offering valuable insights for both academic research and Policymakers.

3. HYPOTHESIS

The association among CO_2 emissions and EG is a crucial topic in the discussion of sustainable development, and it is necessary to evaluate the interaction between education, REC, and EG in the Moroccan setting. Several empirical research show that carbon pollution has a negative impact on economic performance, especially in nations that rely on fossil fuels for their energy.

According to Shahbaz et al. (2013) examined the Indonesian case using data from 1975 to 2011 and found that dioxide carbon emissions have a long-term negative impact on EG, particularly in an environment where fossil fuels are used extensively. This inverse relationship is confirmed by their ARDL analysis. In other context, Al-Mulali et al. (2015) using panel dynamics models, examined 93 countries between 1980 and 2012 and demonstrated that CO_2 emissions can impede growth, particularly in developing nations where pollution levels exceed permitted limits.

Applying Granger's test of causality to Brazilian data from 1980 to 2007, Pao and Tsai (2011) found that CO_2 emissions had a negative long-term influence on real PIB, indicating that carbon reduction policies are essential for sustainable growth. Stern (2007) demonstrates in his seminal report "The Economics of Climate Change" that CO_2 emissions hinder EG through two main channels: direct costs of climate damage (secheresses, inondations) and adaptation costs that divert productive resources. According to its cost-benefit analysis, a reduction in emissions would account for 1-2% of global PIB annually, compared to 5-20% of losses in the absence of climate action.

On the other hand, Apergis and Payne (2010) used PVAR models to examine 80 countries from 1990 to 2006. Their findings show that a 1% increase in emissions lowers growth by 0.12% over the medium term, with a more noticeable effect (−0.18%) in intermediate-income countries. The unique sense of the negative impact is confirmed by the non-significant inverse causality. Dong et al. (2018) introduced a novel approach by measuring the "intensity carbone du PIB" for 120 countries (1995-2014). According to their GMM results, for every 1% increase in PIB in excess of 4.5 tonnes of CO_2, the growth rate increases by 0.23 points. In 60% of emerging economies, this critical threshold has already been surpassed.

In their study published in Energy Economics, Alola and Adebayo (2023) use a Panel ARDL model on 15 highly polluting countries between 1990 and 2020 to analyze the impact of CO_2 emissions on EG. Their findings show that a 1% increase in emissions lowers economic growth by 0.18 percent, with a more noticeable effect in countries where CO_2 emissions per capita are 5.8 tonnes. Additionally, they note that environmental regulations may have an impact of up to 40%. This study highlights the critical role of public policies in limiting the negative effects of CO_2 while providing strong empirical evidence of the short-term compromise between industrialization and sustainability.

The effect is made worse by the inadequate adaptation facilities. Gudarzi et al. (2021) used the QAR (Quantile Regression) method on petroleum exporting countries. Their findings show a U-inverted relationship: the impact of emissions goes from neutral (quantile 25) to strongly negative (−0.31%) to quantile 90, indicating that resource misprediction worsens with carbon intensity. With reference to these findings, the following formulation of the first hypothesis might be made:
H_1: CO_2 emissions negatively impact Economic Growth (EG).

Based on advanced literature, we developed the first hypothesis. However, there are other hypotheses regarding our current paper, including the second, third, and fourth hypotheses. According to Marques et al. (2019) applied a panesian cointegration analysis to 24 OCDE countries from 1980 to 2006. Their findings show that adding 1% more REC to the energy mix results in a long-term increase of 0.07 percent in PIB, with the effect being more noticeable in countries with stable energy policies. According to Omri and Nguyen (2020) applied the GMM method to 64 countries (1990-2016) and found a seuil effect: the impact of REC on growth only becomes significant (+0.15% of PIB) when their share of total energy consumption exceeds 15%. This effect is enhanced by the caliber of the institutions.

In Energy Policy, Dong et al. (2022) use a dynamic GMM model applied to 76 OECD and non-OECD countries between 2000 and 2019 to investigate the effects of REC on EG. According to their findings, because they lessen reliance on fossil fuels, renewable energy sources promote growth more in developing countries (+0.21% PIB for 1% REC) than in developed ones (+0.12%). The study also demonstrates that the optimal effect is achieved when 32% of the energy mix is made up of REC. These findings support the notion that the energy transition may serve as a catalyst for EG, particularly in emerging economies.

In the Southern Africa context, Using a DSGE model applied to southern Africa, Pfeiffer and Mulder (2013) show that investments in REC generate a "double dividend": direct PIB stimulation (+0.3%) and a decrease in pollution-related health costs (1.2% of PIB). Their study emphasizes the significance of targeted subsidies. Ito (2017) introduced a spatial analysis for 47 Asian countries from 1995 to 2014. The findings show that the REC generated favorable regional externalities: Through technological transfers, a 10% increase in a voisin country boosts domestic growth by 0.05%.

In the United States context, Bowden and Payne (2021) investigate the impact of various renewable resources on the United States (1997-2018). Their VAR results show that energy has the strongest influence (+0,09% of PIB by 1% augmentation), followed by solar (+0.06%), while biomass shows declining yields above specific thresholds. On the basis of the advanced literature, the REC contributes to EG. Then, the second hypothesis as follow:
H_2: Economic growth is boosted by REC.

In the other hand, in a study covering 142 countries over the 1990–2019 period, Ahmad et al. (2023) use a seuils analysis to show that the negative impact of public spending on growth is significantly more pronounced in developing countries (−0.21% growth per point of PIB additional expenditures) than in developed countries (−0.08%). This discrepancy is mostly explained by the PED's higher levels of corruption and lower administrative effectiveness, which exacerbate economic distortions. Their model, which controls the endogénéity using GMM, validates the reliability of these findings.

According to Khan et al. (2021) used the SVAR (1995-2018) model to study the effects of growth constraints on the vertebrae (GGCS) in China. Their findings show that a short-term change in environmental regulations lowers the PIB by 0.3 percent, primarily due to a retraction of private investment. But after 5 years, the economy recovered because to increases in energy efficiency. This study highlights the conflict governments face between short-term economic goals and climate change objectives, while demonstrating that initial sacrifices may eventually be recouped.

Plus, Kollias and Paleologou (2019) analyze the years 2010–2022, showing that the negative growth-related elasticities of public spending have increased during the pandemic, moving from −0,12 to −0,19. This decline reflects the rise in "de survie" costs

(undirected assistance) at the expense of public investments. Their dynamic GMM model incorporates institutional heterogeneity among participating nations. Based on advanced literature, the REC contributes to economic growth. Then, the third hypothesis as follow:
H_3: Economic growth is negatively impacted by GGCS.

In plus, according to UNESCO's global report (UNESCO, 2024), every dollar invested in education generates five to fifteen dollars in long-term economic growth. This meta-analysis of 142 countries shows that returns are especially high in middle-income countries where education fills in technological gaps. The document advocates for more educational funding as a long-term development strategy.

In the other hand, Asongu and Odhiambo (2020) evaluate the effects of education on growth in OCDE countries (2000-2018) and sub-Saharan Africa (SSA). Using a DEA analysis and quantitative regressions, they demonstrate that an additional year of education raises PIB/resident by 0.7% in SSA (through the improvement of human capital) and 0.3% in OCDE (through innovation). The study also shows declining results after 12 years of education, highlighting the significance of adjusting educational policies to developmental levels. These findings demonstrate that education is a key component of growth, especially in low-income countries.

The secondary education in Africa accounts for 12% of recent growth, which is more than the contribution of physical capital (8%). The study covering 45 countries shows how skill development has facilitated better continental integration and structural economic restructuring. These findings highlight the potential of human capital as a development lever in emerging nations. The advanced literature suggests that education has a favorable effect on EG (World Bank, 2024). The fourth hypothesis then goes like this:
H_4: Education impacts positively Economic growth.

4. METHODOLOGY AND DATA SOURCES

The selection of the data is based on its longitudinal availability and relevance to emerging nations, with a particular emphasis on developing economies. The variables were extracted from the WDI's standardized chronology series, ensuring their international comparability. Thus, this platform provides a strong framework for analyzing macroeconomic and socioenvironmental dynamics while taking into account the limitations inherent in secondary data (e.g., ponctuelle gaps, variable collection methods) (Table 1).

In the other hand, this Figure 1 shows the important relationships between several macroeconomic, environmental, and social indicators. The GDP per capita (in US dollars) variable, which serves as a stand-in for EG, is located at the center of the diagram. Two main hypotheses (H_2 and H_3) relate this variable to other factors: on the one hand, carbon dioxide emissions that reflect environmental impact, and on the other hand, GGCS that reflect state intervention.

In plus, the Figure 1 also includes two supplementary indicators: the percentage of renewable energy in total energy consumption, which highlights the significance of the energy transition, and the primary school graduation rate (for both girls and boys, expressed in percentage brute) as a measure of education. These visual connections highlight the intricate relationships between economic development, public policy, education, and environmental sustainability, providing a conceptual framework for analyzing their interdependent dynamics.

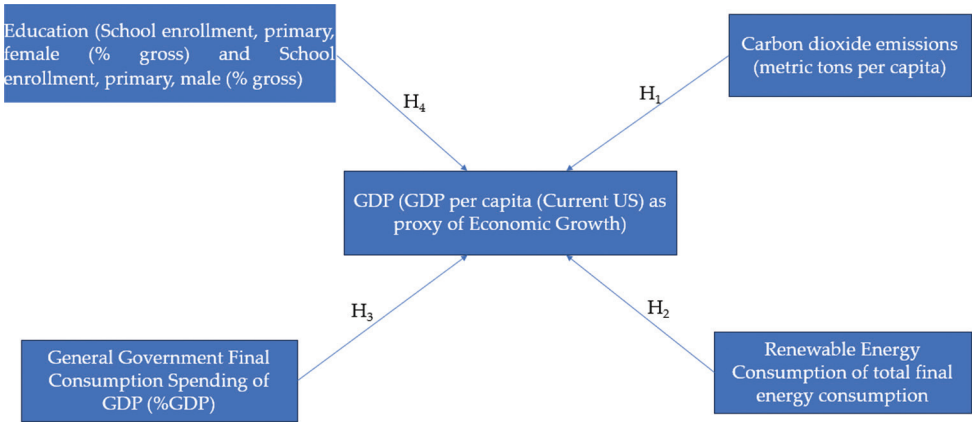
In this study, we utilize the ARDL to investigate correlations between the LT long-term and ST short-term variables with different integration orders. According to Anaduaka (2014), the ARDL is superior to previous cointegration approaches in three ways: (1) it performs better with smaller data sets; (2) it can deal

Table 1: Data sources

Description	Data type	Source
GDP (GDP per capita (Current US) as proxy of Economic Growth)	Annually data (1993–2020)	WDI (2024)
Education (School enrollment, primary, female (% gross) and School enrollment, primary, male (% gross)	Annually data (1993–2020)	WDI (2024)
Carbon dioxide emissions (metric tons per capita)	Annually data (1993–2020)	WDI (2024)
General Government Consumption Spending of GDP (%GDP)	Annually data (1993–2020)	WDI (2024)
Renewable Energy Consumption of total final energy consumption	Annually data (1993–2020)	WDI (2024)

Source (s): Created by authors

Figure 1: Conceptual framework



with variables that have different integration orders (I [1] or I [0]); and (3) it generates accurate long-term model predictions.

The optimal lag number (p, q) for our model will be estimated using the Hannan-Quin, Schwarz-SIC, and Akaike-AIC information criteria. Our suggested model is based on a larger corpus of literature, particularly Raihan and Voumik. (2022). These WDI-sourced data were used by us in our analysis. The parameters selected have their origins in previous empirical studies conducted in this area.

Increasing government expenditure encourages consistent economic growth, according to the Keynesian paradigm. This paper examines the Cobb-Douglas production function through a theoretical lens. The Pedroni model states that S is a productive energy and that Y = f(K, L, S) represents the energy needed for EG, indicating that this is not the case. The study model is as follows:

$$Y = f(\text{EDUCATION}, CO_2 \text{ emissions}, \text{REC}, \text{GGCS}) \quad (1)$$

where Y is the current GDP per capita in the US and Education measured by School enrollment, primary, female (% gross) and School enrollment, primary, male (% gross) are used as proxies for education. REC is the proportion of renewable energy to total final energy consumption; CO_2 emissions are represented in metric tons per person; HC stands for human capital; and GGFCS is the GDP percentage. Our organization:

$$\text{GDP per capita}_t = \alpha_0 + \alpha_1 \text{Education}_t + \alpha_2 CO_2 \text{ emissions}_t + \alpha_3 \text{REC}_t + \alpha_4 \text{GGCS}_t + \varepsilon_t \quad (2)$$

The stochastic disturbance term is represented by ε.

For example, an ARDL is employed in this study for technical estimation, following Pesaran and Shin's (1995) description. In cases when using the existence of a single cointegrating vector (Johansen integration) is impractical, they provided a way to cointegrate a bound technique for long-term connections. This technic is known as ARDL and it disregards the degree of stationarity. ARDL approximation is more precise and effective.

In addition, the variables model's SR and LR link definitions are produced by the results of the ARDL parameterization. Simply put, the use of the following indicators represents education: School enrollment, primary, female (% gross) and School enrollment, primary, male (% gross). But it brings us back to the same. In Table 2, descriptive variables as follow.

The most volatile variable is GDP per capita (the current US GDP), which is established by the descriptive analysis of these variables; the least volatile variable is the amount of CO_2 released per capita, as defined by the kind of standard deviation values. Additionally, school enrollment, primary, female (% gross) is 93.51785, and school enrollment, primary, male (% gross) is 104.1393, representing the respective values of education. All research variables, apart from the variable School enrollment, primary, male (% gross), are explained in detail by this descriptive study. The findings indicate that the research variables have a normal distribution and a Jarque-Bera probability greater than 5%. Because of their smaller kurtosis coefficients (less than 3), most variables have flatter distributions than the normal distribution.

4.1. Unit Root Test

A statistical test called a unit root test is used to assess if a time series variable has a unit root and is non-stationary. A unit root is a stochastic trend in a time series that has a root value of one. Stated differently, a unit root process is one in which the process's expected value is not constant over time but rather varies wildly within a certain range.

The results in Table 3 show that the model variables are steady in the first difference I(1) and the education (School enrollment primary, male and female) variable in the second difference I(2). Stock and Watson describe ARDL models as the lag in delicate selection orders. For this econometric analysis, the model with the lowest (SIC) and (AIC) is selected. Between 2005 and 2011, Morocco's share of REC in its total ultimate energy usage decreased. A non-stationary series is one that exhibits a unit root. The unit root (UR) of a test determines the integration directive for variables in the model.

The integration order of the model variables can also be ascertained with the aid of the test's unit root. In this model, a well-known and helpful control that evaluates the series' stationarity is the test (ADF).

Table 2: Descriptive statistics

Parameters	EG	School enrollment, primary, female (% gross)	School enrollment, primary, male (% gross)	CO_2	GGCS	REC
Mean	2460.017	93.51785	104.1393	1.446758	16.99462	14.70143
Median	2592.318	101.1506	110.0076	1.471459	16.90606	15.03000
Maximum	3498.583	110.6991	114.3141	1.955308	19.40499	22.97000
Minimum	1217.429	55.73833	78.06779	0.991096	14.30467	10.45000
Std. Dev.	833.8227	17.25169	11.00806	0.290854	1.286759	3.290203
Skewness	−0.153952	−1.046647	−1.193790	−0.054651	−0.034499	0.413372
Kurtosis	1.311911	2.558469	2.930188	1.623676	2.109225	2.587370
Jarque-Bera	3.435192	5.339631	6.656315	2.223916	0.931281	0.996063
Probability	0.179497	0.069265	0.035859	0.328914	0.627733	0.607726
Sum	68880.49	2618.500	2915.901	40.50922	475.8494	411.6400
Sum Sq. Dev.	18772027	8035.763	3271.787	2.284099	44.70524	292.2867
Observations	28	28	28	28	28	28

Source (s): Authors

Table 3: Stationarity test

Variables	Series		P-value	Series in first difference		P-value	Series in second difference		P-value
	Test statistic	Dickey-Fuller critical value (5%)		Test statistic	Dickey-Fuller critical value (5%)		Test statistic	Dickey-Fuller critical value (5%)	
GDP per capita	1.631693	−1.953858	0.9717	−3.804519	−1.954414	0.0005	-	-	-
School enrollment primary, female (% gross)	0.498605	−1.954414	0.8163	−1.449701	−1.954414	0.1341	−4.083258	−1.955020	0.0002
School enrollment primary, male (% gross)	0.721043	−1.954414	0.8646	−1.834420	−1.954414	0.0642	−5.126654	−1.955020	0.0000
CO_2 emissions	3.217145	−1.954414	0.9992	−4.663002	−1.954414	0.0000	-	-	-
GGCS	0.173015	−1.953858	0.7285	−8.329758	−1.954414	0.0000	-	-	-
REC	−0.996210	−1.953858	0.2782	−4.993035	−1.954414	0.0000	-	-	-

Source (s): Created by authors

A crucial first step in ensuring the validity and dependability of an economic analysis's conclusions is figuring out how many delays to include in an ARDL model. The dynamics and coefficient estimate of the model are directly impacted by the number of lags utilized, which are represented as pp for dependent variable delays and qq for explicative variable delays. Regression diagnoses that do not support the required hypotheses, estimate bias, and adjustment issues might arise from a poor choice of delays. The maximum amount of delays that should be included in an ARDL model can be decided using a number of selection criteria, such as the Hannan-Quinn (HQ), Bayesian information criteria, and AIC.

Values indicating the model's complexity in relation to the estimated number of parameters are produced by each of these criteria. Generally speaking, these criteria indicate a balance between the model's simplicity and adjustment, which is essential to avoid over-adjusting. For instance, the AIC prefers more intricate models than the BIC, which, depending on the context of the research, could have important implications. The above table shows the maximum delay that can be used with (FPE), (SBIC), (AIC), and (HQIC). By comparing the lowest values of each lag that follow one another, the ideal lag of two is found (22.07963 for FPE, 19.68716 for AIC, 22.07259 for SBIC, and 20.62551 for HQIC).

As Table 1 illustrates, the first stage in model estimating is the ARDL regression at the best distributed lags constructed on the AIC. Finally, in order to examine the robustness of the ARDL model, it is wise to move forward with the examination of the selection of delays from a cross-validation or an evaluation on sub-examples.

By using this approach, it is able to examine the stability of the coefficients and verify that the selected model is not especially suited to a certain collection of data. Ultimately, determining the maximum amount of delays in an ARDL model is a challenging process that requires a blend of theoretical standards, empirical research, and critical outcome assessment to produce reliable and significant findings.

ARDL is an economic method for examining long-term correlations between variables. In other words, the ARDL approach offers a great deal of flexibility in the analysis of historical series, even when certain variables are fixed while others go through a differentiation process. It demonstrates that GGFCE as a GDP percentage has a statistically significant negative influence on EG, while CO_2 and the proportion of final energy derived from renewable sources have a favorable impact. Additionally, school enrollment for both genders has a good effect on EG.

The capacity of the ARDL technique to produce models that faithfully capture the temporal dynamics of the variables being studied is one of its primary benefits. Because the consequences of economic policies or external shocks may manifest throughout a given time span, this feature is very useful in economic studies. Furthermore, the computation of long-term coefficients using the ARDL test of relations of equilibrium of co-integration allows for the drawing of strong conclusions about long-term impacts.

Nevertheless, the ARDL approach requires careful consideration of the model's stability evaluation and suitable delay selection. Co-integration tests, such as the Bounds test, can be used to confirm long-term links between the variables. Verifying that the model's residuals support the non-autocorrelation and homoscedasticity hypotheses is also crucial. To guarantee the authenticity of the findings, the proper diagnostic procedures must be followed. To sum up, the ARDL technique is an effective instrument that allows for a detailed examination of complex interactions between economic variables within a temporal framework, making it useful for both social scientists and economists.

The AIC is a widely used statistical measure for selecting models in economics and statistics. Hirotsugu Akaike proposed this criterion in 1974 with the intention of evaluating a statistical model's quality while emphasizing its intricacy. When evaluating several models to see which one offers the best balance between accuracy and parity, the AIC is particularly useful.

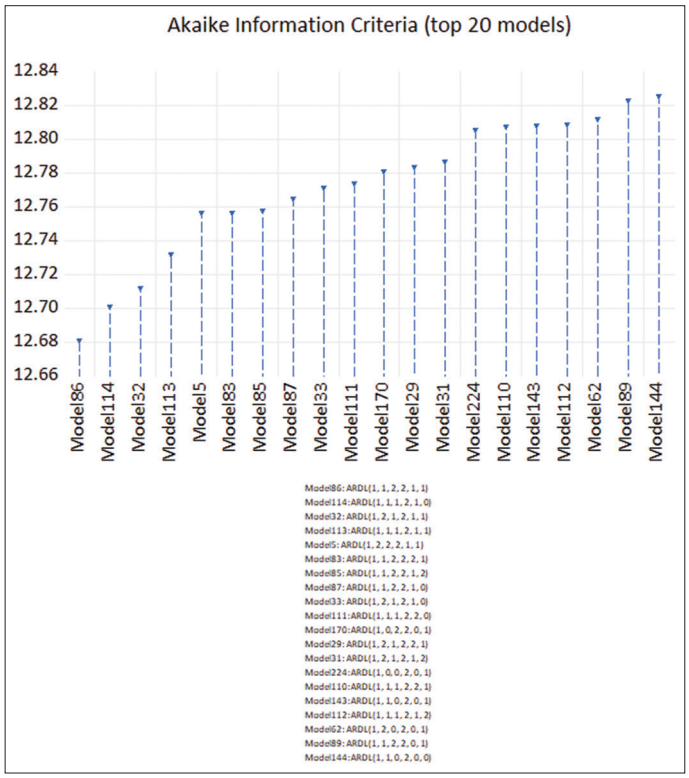
It is appropriate for a variety of models, such as regression models, historical series models, and other statistical model types, because its basis is the maximization of likeness. After Figure 2, we will choose the model with the least amount of information, making Model 86 (1,1,2,2,1,1) our best model.

In conclusion, the AIC offers a rigorous method for analyzing and evaluating different statistical models, making it a useful

tool in the model selection process. Because of its theoretical underpinnings in the maximization of likeness and its versatility across different model families, researchers choose this method. To produce trustworthy and pertinent data analysis results, it must be used in combination with additional selection criteria and qualitative evaluations.

Estimating the explanatory variable coefficients is a crucial step in the short-term relationship analysis with the ARDL. These coefficients, which represent the dependent variable's immediate reaction to changes in the explanatory factors, offer a precise comprehension of the short-term economic dynamics. For instance, if one looks at how a fiscal chock affects consumption, the model can show not only the immediate effect but also how this effect changes over time, which is crucial information for policymakers.

Figure 2: Selection of optimal lag



Long-Run (LR)

Variable	Coefficient	Std. error	t-statistic	Prob.
SCHOOL_ ENROLLMENT_ PRIMARY_ FEMALE_ GROSS	144.1692	30.89285	4.666749	0.0005
SCHOOL_ ENROLLMENT_ PRIMARY_ MALE_GROSS	−231.6206	45.16221	−5.128637	0.0002
CO_2 EMISSIONS	3405.400	553.5905	6.151479	0.0000
GGCS	−221.0496	59.03137	−3.744612	0.0028
REC	40.77597	30.50635	1.336639	0.2061
C	11501.20	1803.911	6.375705	0.0000

EC=GDP_PER_CAPITA_CURRENT_US - (144.1692 *SCHOOL_ENROLLMENT_PRIMARY_FEMALE_GROSS −231.6206*SCHOOL_ENROLLMENT_PRIMARY_MALE_GROSS+3405.4000*CO2_EMISSIONS_METRIC_TONS_PER_CAPITA_ −221.0496*GENERAL_GOVERNMENT_FINAL_ CONSUMPTION_EXP ENDITURE_OF_GDP+40.7760*RENEWABLE_ENERGY_CON SUMPTION_OF_TOTAL_FINAL_ENERGY_ CONSUMPTION+11501.2024)

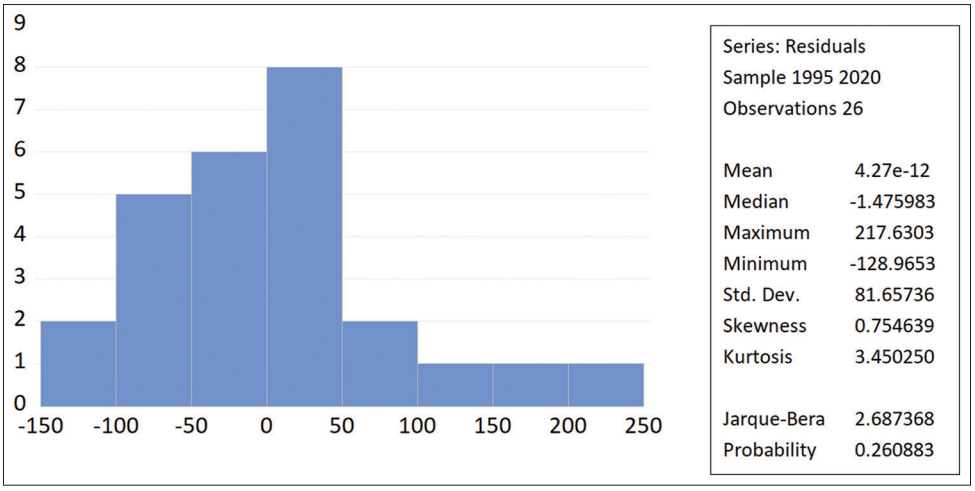
Source (s): Created by authors

Furthermore, the ARDL approach makes it possible to study the dynamics of long-term adjustment toward equilibrium, even in a short-term framework. Even while the model focuses on the immediate effects, it may also include a term for correction error that describes how short-term imbalances correct themselves to the long-term equilibrium relationship. This provides an integrated perspective on economic adjustments, enabling a better understanding of how short-term setbacks might impact longer-term trends.

Adjustment (ADJ)				
Variables	Coefficient	Std. error	T	P > |t|
GDP per capita (−1)	−1.232681	0.183626	−6.712988	0.0000

Source (s): Created by authors

Figure 3: Normality test



Therefore, whereas GGFCE (% of GDP) and primary male school enrollment (education) have a negative effect on EG, REC and CO_2 have a positive effect, according to the LR coefficients in Table 4's second portion. The findings of Fikri and Rhalma (2024) and Hanadi (2024) are supported by this result. But school enrollment primary female has a positive impact on EG. The speed of adjustment was shown as a negative number (−1.232681) in Table ADJUSTMENT to the GDP per capita, in the third section of Table 5. This figure shows how quickly the equilibrium is distorted or how much the dependent variable reacts to a change in the equilibrium link over a specific amount of time.

An important economic technique for assessing the co-integration of variables within the framework of ARDL models the bound test (Table 7), often known as the bound test. Comparing this to traditional cointegration tests, which require that all variables be integrated in the same order, reveals a significant advantage. The most important part of the process is already completed: confirming the cointegration of public revenue and expenditures to ascertain whether Morocco's public debt can be maintained.

Anaduaka (2014) claims that the Pesaran cointegration test can accomplish this. The test is explained in detail in advance, and the generated statistical value is compared to significant values (which establish limits). There are three possible outcomes:

- There is no cointegration if the Fisher value is less than the lower bound; no inference can be made if the Fisher value is divided between the two bounds.
- The two variables are cointegrated when the Fisher value is greater than the upper constraint.

However, although being a significant methodological advancement, the examination of bearings has major limits. The results may vary depending on how the model is specified, including the variables and delay settings. A

As a result, special attention needs to be paid to choosing appropriate delays and validating the results through robustness tests. Overall, the test of bearings is a very useful tool for economists, helping to better understand long-term economic dynamics and making complex relationships between economic variables easier to analyze. Plus, the Table 5: The ARDL regression results bound assessmentsIt is possible to assess the long-term impacts between the variables because the value of F: 4.291829 is greater than the 4.134 1% significance level limit.

This shows that there is a link of cointegration. With the F crucial values = 4.291829, the F-statistic, which was generated using the data from Table 6, is 2.39 more than 1%. The test thus rejects the null hypothesis. A Long-Run (LR) relationship between the exogenous and endogenous variables is implied. First, heteroscedasticity is necessary to diagnose this model. Thirdly, model stability; and second, normalcy. To ascertain whether the variance of the model residuals is homoscedastic or constant, one must comprehend heteroscedasticity. determining the connection between the independent variables and the presence of the model residuals. Because it is based on the Chi-Square distribution and can be used in conjunction with other techniques, the White test is a helpful tool for verifying heteroscedasticity. Since there is no heteroscedasticity, the estimated model residuals are distributed randomly (Figure 3).

Prior to creating prediction intervals and conducting Student parameter tests, confirm that the errors are normal. Using the ideas of skewness (asymmetries) and Kurtosis (aplatissement). The earlier findings support this theory since the residuals are white Gaussian noises with a normal distribution if the Jarque-Bera probability is greater than 5%. Verifying that the errors are normal is necessary before completing Student parameter tests and calculating prediction intervals. applying the concepts of Kurtosis and Skewness. The sensitivity of the Jarque-Bera test to both asymmetry and data plating is one of its primary advantages, which makes it a useful instrument for identifying departures from normalcy. This is particularly pertinent to economic research, as the validity of statistical conclusions is sometimes dependent on the residuals' normality premise.

Because a dataset with significant kurtosis or severe asymmetries may impact the regression models' output, this test is essential

Table 4: Maximum number of lags

Number of lags	Final prediction error	AIC	SIC	HQ
0	107805.4	28.61512	28.90545	28.69872
1	22.07963*	20.04028	22.07259*	20.62551*
2	25.83080	19.68716*	23.46145	20.77402

Source (s): Created by authors

Figure 4: The CUSUM

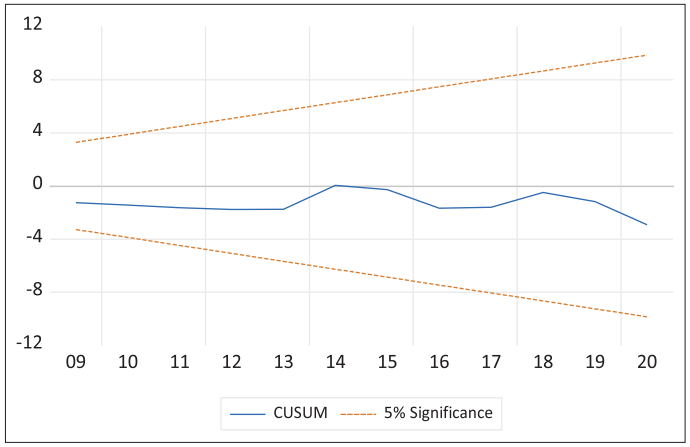


Figure 5: The CUSUM of Squares

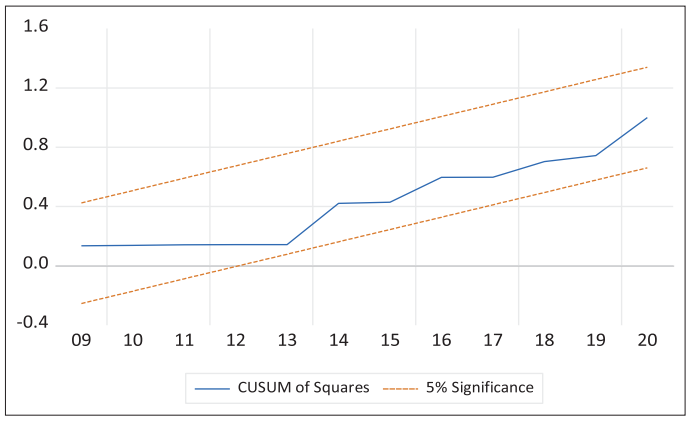


Table 5: Optimal model of ARDL approach

Variable	Coefficient	Std. error	t-statistic	Prob.*
EG (−1)	−0.232681	0.271794	−0.856094	0.4087
SCHOOL ENROLLMENT PRIMARY FEMALE GROSS	31.70793	85.33041	0.371590	0.7167
SCHOOL ENROLLMENT PRIMARY FEMALE GROSS (−1)	146.0066	81.17767	1.798606	0.0973
SCHOOLENROLLMENT PRIMARY MALE GROSS	−139.4424	97.68551	−1.427462	0.1789
SCHOOL ENROLLMENT PRIMARY MALE GROSS (−1)	−101.1980	102.5759	−0.986567	0.3433
SCHOOL ENROLLMENT PRIMARY MALE GROSS (−2)	−44.87389	35.15034	−1.276627	0.2259
CO_2 EMISSIONS	1047.730	620.5484	1.688394	0.1171
CO_2 EMISSIONS (−1)	571.4672	695.1169	0.822117	0.4270
CO_2 EMISSIONS (−2)	2578.574	958.9991	2.688818	0.0197
GGCS	−161.9434	41.33286	−3.918031	0.0020
GGCS (−1)	−110.5402	64.55274	−1.712402	0.1125
REC	10.67396	20.88274	0.511138	0.6185
REC (−1)	39.58980	27.38778	1.445528	0.1739
C	14177.31	3462.432	4.094612	0.0015

Source (s): Created by authors

Table 6: The outcomes of the ARDL Adjustment (ADJ), Long-Run (LR), and Short-Run (SR)

Short-Run (SR)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	14177.31	3462.432	4.094612	0.0015
EG (−1)*	−1.232681	0.271794	−4.535354	0.0007
SCHOOL ENROLLMENT PRIMARY FEMALE GROSS (−1)	177.7146	46.49109	3.822551	0.0024
SCHOOL ENROLLMENT PRIMARY MALE GROSS (−1)	−285.5143	71.75842	−3.978826	0.0018
CO_2 EMISSIONS (−1)	4197.772	1056.503	3.973270	0.0018
GGCS (−1)	−272.4836	87.98108	−3.097071	0.0092
REC (−1)	50.26376	35.68048	1.408719	0.1843
D (SCHOOL ENROLLMENT PRIMARY FEMALE GROSS)	31.70793	85.33041	0.371590	0.7167
D (SCHOOL ENROLLMENTPRIMARY MALE GROSS)	−139.4424	97.68551	−1.427462	0.1789
D (SCHOOL ENROLLMENT PRIMARY MALE GROSS (−1))	44.87389	35.15034	1.276627	0.2259
D (CO_2 EMISSIONS)	1047.730	620.5484	1.688394	0.1171
D (CO_2 EMISSIONS (-1))	−2578.574	958.9991	−2.688818	0.0197
D (GGCS)	−161.9434	41.33286	−3.918031	0.0020
D (REC)	10.67396	20.88274	0.511138	0.6185

*P-value incompatible with t-Bounds distribution. Source (s): Created by authors

Table 7: The bound test

F-Bounds test		Null hypothesis: No levels relationship		
Test statistic	**Value**	**Significant (%)**	**I (0)**	**I (1)**
			Asymptotic: n=1000	
F-statistic	4.291829	10	2.08	3
k	5	5	2.39	3.38
		2.5	2.7	3.73
		1	3.06	4.15
Actual sample size	26		Finite sample: n=35	
		10	2.331	3.417
		5	2.804	4.013
		1	3.9	5.419
			Finite sample: n=30	
		10	2.407	3.517
		5	2.91	4.193
		1	4.134	5.761

Source (s): Created by authors

to ensuring accurate and trustworthy regression analysis. The likelihood of Jarque bera 0.260883 in our situation is more than 5%. Two useful statistical techniques for locating structural cracks in economic models are the CUSUM (Cumulative Sum Control Chart) and CUSUM of Squares (CUSUM of Squares) tests. In the context of historical series, where political upheavals, economic downturns, or other exogenous events may cause changes in the connection between the variables, these tests are particularly crucial. While the CUSUM des carrés test examines the stability of the residual variance, the CUSUM test evaluates the stability of a model's coefficients by examining the sum of the standardised residuals (Figures 4 and 5).

Furthermore, the CUSUM of Squares test—that is, the CUSUM of the squares of the cyclical residuals—is the most effective method for assessing the model's stability. The interval's two right-hand branches serve as its limits. Based on the previous graph, which shows the CUSUM of Squares and CUSUM findings' test, we can conclude that the estimated model is stable because the curve does not deviate from the pointily. A comprehensive evaluation of the models' stability is made possible by the combined use of the CUSUM and CUSUM of squares tests.

However, as not all ruptures seen require the model to be rejected, particular care must be used in how the results are interpreted. It is crucial to contextualize these splits within the framework of economic analysis while taking structural changes and other external events into account.

To guarantee a complete grasp of the dynamics underlying the data, it is therefore recommended to include qualitative research and

alternative models to the CUSUM and CUSUM of squares tests. As a result, the coefficients remain constant over time.

In conclusion, because they offer a trustworthy way to spot structural changes in the relationships between variables, the CUSUM and CUSUM of squares tests are essential instruments for evaluating the stability of economic models. Its use strengthens the validity of inferences made from data studies and emphasizes the importance of a multifaceted approach in evaluating economic models. Researchers can more readily manage the intricacy of chronological series and gain crucial insights into economic processes by incorporating these criteria into the analytic process.

5. DISCUSSION

By using an ARDL method to the relationship between education, renewable energy consumption, and economic growth, the study's findings support the Moroccan evidence. The percentage of GDP spent on GGCS, the number of primary female and male students enrolled in school, the amount of CO_2 emissions per capita, and the percentage of total final energy consumption spent on RECs are all examples of exogenous variables that, in fact, exhibit an LR relationship, according to the model test results. The following research.

The study's conclusions further bolster the long-term advantages of CO_2 emissions and REC on Morocco's EG. Anaduaka (2014); Raihan and Voumik (2022); Gudarzi et al. (2024) and According to Alola and Adebayo (2023) their study demonstrates that increased CO_2 emissions lower economic productivity, especially in high-energy intensity businesses. H_1 is approved in this study.

According to Dong et al. (2022) and Bowden and Payne (2021), the economic growth is stimulated by renewable energy sources because they attract investments and lessen reliance on fossil fuels. So H_2 is approved in this study.

In the other hand, the restrictions associated with green growth policies, such as rigorous regulations, may temporarily impede economic growth before producing long-term benefits (Khan et al., 2021; Ahmad et al., 2023). So, the hypothesis H_3 is confirmed.

In 2020, Asongu and Odhiambo (2020), the productivity and innovation are enhanced by high-quality education, which promotes economic growth, especially in developing nations. Conversely, female primary school enrollment has a positive long-term impact on EG; for this reason, hypothesis H_4 is accepted.

This study uses an ARDL approach to examine the relationships between education, renewable energy consumption, and economic growth in Morocco. It is distinguished by the incorporation of important variables such as public education spending, primary school enrollment rate (particularly among children), CO_2 emissions per capita, and the share of renewable energy sources in overall consumption.

The findings support a long-term relationship between these factors and economic growth. The analysis shows that while CO_2 emissions hinder productivity, renewable energy sources boost growth by drawing in investments and lowering reliance on fossil fuels.

Furthermore, even though severe regulations may have a short-term limiting effect, green growth policies produce long-term benefits. Last but not least, the study emphasizes how education, particularly female scolarization, influences increased productivity and innovation, which in turn supports economic growth. These findings add to the body of knowledge on emerging economies while providing Morocco's policymakers with relevant avenues for energy transition, educational reform, and sustainable growth.

6. CONCLUSION

The interplay between education, carbon dioxide emissions (CO_2), REC, GGCS, and EG represents a complex and multifaceted area of inquiry in contemporary economics and environmental studies. Understanding these relationships is vital, as they inform policies aimed at sustainable development and economic resilience. Each of these factors can significantly influence EG, either positively or negatively, depending on the context and the interplay among them.

The links between EG and school enrollment, both short- and long-term, were accepted in the side of Education. Empirical and study-based studies have demonstrated that there are differences in the relationships between GGCS, CO_2 emissions, REC, and EG sustainability. The results showed that the variables' tests had a temporal association. However, the study's conclusions disproved the Keynesian premise by showing that GGCS negatively impacts EG. The findings which may be related to shortcomings in the research and development process. government support for scientific research and development is crucial to the continued existence of EG. The results of the study also showed that the percentage of GGCS that originates from the usage of REC and CO_2 emissions have a positive association (impact) and boost EG.

Presuming that there is a causal relationship between the use of RE and both EG and CO_2 emissions, Morocco's use of renewable energy is starting to have a positive effect. In terms of the financial components of sustainable development, this study looked at how Morocco's ability to achieve sustainable economic growth between 1993 and 2020 was impacted by REC, general government final consumer spending as a proportion of GDP, and CO_2 emissions. In summary, there are intricate and interconnected links between education, CO_2 emissions, REC, GGCS, and EG.

Every element affects every other one, and the overall effect of all of these factors on economic growth needs to be comprehended in the context of sustainable development. Future studies should concentrate on empirical analyses that investigate these relationships in diverse settings, taking into account the possible moderating impacts of social norms, institutional quality, and technological innovation. These kinds of studies will be crucial to developing evidence-based policies that address environmental concerns and advance sustainable EG.

Even though this study offers useful findings about the connections between education, renewable energy, and economic growth in Morocco, there are a few limitations to take into account. First of all, the analysis focuses on aggregated data, which may conceal significant regional or sectoral disparities in a nation with notable socioeconomic inequalities. Second, although the ARDL model is effective in identifying long-term relationships, it is unable to establish exact causality between variables. Thirdly, several relevant factors that could affect the results have not been included, such as technological progress or the flow of foreign investments in renewable energy. Last but not least, the study is based on national data, which may be impacted by statistical bias or gaps in the measurements, particularly for environmental and educational indicators. These limitations imply that future studies could expand the analysis by include disaggregated data, more reliable economic methods, and more variables for a more thorough understanding of the dynamics under study.

This study opens up a number of avenues for further research on the connection between education, renewable energy, and economic growth in Morocco. One approach would be to expand the analysis by including data that has been de-categorized by region in order to assess the regional differences in the effects of energy and education policies. To determine which industries are most receptive to the green transition and what skills are needed, a sector-specific approach may also be envisaged. Furthermore, the addition of supplementary variables, such as foreign direct investments in domestic energy, technological innovation, or even gender disparities in educational access, allowed for the refinement of the results. The use of advanced economic techniques, such as panel dynamic approaches or models with simultaneous equations, may also increase the reliability of the findings.

Furthermore, a comparison analysis with other emerging nations, such as those that share characteristics with Morocco, would provide a more comprehensive understanding of the mechanisms at work. Finally, qualitative research—such as surveys or case studies—could supplement quantitative analyses by examining how local actors—such as businesses, political decision-makers, and populations—perceive the opportunities and challenges associated with green growth. These many paths enhanced academic literature on transition economies while also helping to clarify public policies for sustainable development.

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