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Effect of Renewable Energy Consumption, Artificial Intelligence, and Education on Economic Growth for Period 1993-2023: Quantile Regression-ARDL Approach

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ABSTRACT

Since education affects environmental practices, energy transition, and economic growth, it is a crucial part of sustainable development. The rise in the rate of solarization in Morocco is a result of public education activities that could boost technical innovation and productivity. The purpose of this study is to ascertain how Morocco affects economic growth (EG), education, general government consumption spending (GGCS), artificial intelligence (AI), and renewable energy consumption (REC). To assess the short- and long-term correlations between the model's variables, this study combined the least squares ordinary approach with a Quantile Regression-ARDL Approach for stationarity and distributed deterioration. Annual data from 1993 to 2023 from the International Energy Agency (IEA), World Development Indicators (WDI), and Energy Progress Report have been gathered for the study. Long-term relationships were evaluated using the bound test, and heteroscedasticity in the model residuals was examined using the White test. Numerous connections between independent and dependent variables were shown by empirical study. While the dependent variable was stationary in the first difference, the actual data demonstrated that the independent variables were not stationary in the first difference but became stationary in the second. A long-term association between independent and dependent variables was validated using the bound test-based model simulation. The short- and long-term connections between EG and schooling, however, were refuted. There were no indications of heteroscedasticity in the model residuals. The results show how education, AI, REC, GGCS, and economic growth interact in a multifaceted way in Morocco. When creating policies for sustainable development, policymakers should take these relationships into account, especially when attempting to strike a balance between environmental sustainability, educational advancement, and economic growth.

Keywords: Artificial Intelligence, Renewable Energy Consumption, Education, Economic Growth, Morocco
JEL Classifications: E21, E61, E66, E42

1. INTRODUCTION

Artificial intelligence facilitates the use of territorial resources in the most efficient and profitable ways. Consequently, AI has a favorable impact on the ecosystem of economic intelligence. Since education affects environmental practices, energy transition, and economic growth, it is a crucial part of sustainable development. The rise in the rate of solarization in Morocco is a result of public education

activities that could boost technical innovation and productivity. The purpose of the current study is to ascertain how Morocco affects economic growth (EG), education, general government consumption spending (GGCS), CO2 emissions, and renewable energy consumption (Fikri, 2025). Modern theory of education emphasizes that not only do labor and capital factors contribute to the evolution of economic growth at various levels across economies, but that the quality of the labor factor itself is a critical factor influencing economic growth. This contrasts with conventional theory, which maintains that only these factors contribute. Human funds and EG have long piqued the interest of politicians and scholars. According to Anaduaka (2014), the term "human capital," which is sometimes used interchangeably with "human resources," refers to the variety of skills, abilities, knowledge, and experiences that people bring to their workstation. As wealth shifts from traditional industries to knowledge-based sectors, the goal of human capital in promoting EG has increased (Begum et al., 2015).

Several, though not always obvious, connections between human capital and an economy's capacity for innovation and productivity growth have led to the development of new growth models that emphasize education and its importance for a nation's economic performance (Bouyghrissi et al., 2021). EG Cameron will benefit from an educated staff since it can foster innovation and production (Cameron and Trivedi, 2005). EG is a key concept in economics that describes the gradual rise of a country's output of goods and services over time. Additional indicators of economic progress include employment, human development, and per capita income (Chen et al., 2020). The connection between EG and human capital has long piqued the imagination of academics and policymakers (Devassia et al., 2024). However, AI is crucial for wide adoption to improve well-being and revitalize sluggish productivity development, as well as for fostering macroeconomic innovation across a variety of industries. However, several barriers hindered the human involvement process. A computer system with human-like senses, cognition, and behavior is referred to as artificial intelligence (AI) (Brynjol, 2023).

One of the most urgent issues confronting our globe right now is climate change and its effects on the environment (Fikri and Rhalma, 2024). The association between GGCS, REC, and EG sustainability has been shown to be inconsistent by studies and empirical research (Haji, 2011). However, domestic investment is required to establish a solid basis for long-term economic growth and innovation. Economic theories such as Big Push theory and Keynesian demand to improve public goods and, consequently, improve economic well-being in an economy have highlighted the need for increased government spending (Hanadi, 2024). Solow's growth paradigm identifies the primary drivers of economic growth (Howitt and Aghion, 1998). Furthermore, Morocco is aware that climate change is becoming a major global concern. One of the nations now engaged in short- and medium-term renewable energy development initiatives is Morocco. Morocco's economic performance, the amount of GDP spent on final consumption by public administrations, education, AI, and the proportion of renewable energy sources in overall energy consumption are all factors that the current study aims to examine. His goal is to present a fresh viewpoint on these relationships, particularly considering Moroccan culture. A lot of attention has been paid to the relationship between EDUCATION, REC, AI, GGCS, and EG in the economic literature, which has also looked at the use of AI, Education, REC, GGCS, and EG.

The current study aims to examine the relationship between AI, REC, EDUCATION, GGCS, and EG from 1993 to 2023. The rise in the rate of solarization in Morocco is a result of public education activities that could boost technical innovation and productivity. The goal of this work is to close this gap. By analyzing the dynamics of education, the use of renewable energy, and economic growth in the Moroccan setting, this study adds to the body of previous work. It challenges several common beliefs, such as the direct short-term influence of education on economic growth and offers empirical support for the long-term correlations between these variables. The impact of education, artificial intelligence, REC, and GGCS on Moroccan EG between 1993 and 2023 is our issue. For Moroccan officials, this is significant because it allows them to create strategies for sustainable growth that balance economic development with environmental protection. The following is a framework for this essay: (2) Literature Review (3) Hypotheses (4) Methodology and Data (5) Discussion. (6) Conclusion (7) Implications and recommendations (8) References.

2. LITERATURE REVIEW

It became essential to assess the development model and take education into account as a factor affecting EG. As a result, in the 1960s, the contemporary conception of human capital was developed. This hypothesis is based on the idea that a quality work factor requires both an accessible healthcare system that allows for the reproduction of these physical attributes and a contemporary educational system that emphasizes the sciences, innovation, and technology (Joachim, 2021). Two economists from the University of Chicago, Theodor Schultz and Gary Backer, emphasize the importance of education in developing human capital that can achieve national productivity. According to Schultz, training includes all the abilities, know-how, and skills needed to increase worker productivity at work. Keynes (1936) said that wage differences between workers and people depend on how long a person attends a university or college. It is essential to determine the acceptable assessment of the benefits and drawbacks of the length of a person's study and training period in relation to the returns on investment since a degree must enable them to work more productively and earn more money (Joachim, 2021). It has been challenging to comprehend how AI technologies affect economic aggregates (Seamans and Raj, 2018). Although the findings pertain to a micro analysis, spending on education and training directly increases the productivity of the national economy at the macro level.

According to Kripfganz and Schneider (2020), this in turn draws talented workers to high value-added industries focused on innovation and technology. The amount of economic study has clearly shown that a country's ability to expand economically is influenced by its human capital. Spending on education and training directly boosts the macroeconomic productivity of the country, even though the results are based on a micro analysis.

Kripfganz and Schneider (2020) claim that this in turn attracts skilled workers to high-value companies that prioritize technology and innovation. Numerous economic studies have unequivocally demonstrated that a nation's human capital affects its capacity to grow economically. Meltzer (1981) research on the returns on education, which showed a positive and stable correlation between educational attainment and production across a range of industries and countries. Pedroni (2004) shown how human resources drive EG in emerging nations by highlighting a positive relationship between economic performance and the development of human resources in their studies on African nations like Nigeria. Since gaining independence, Morocco has dedicated itself to achieving goals aimed at generating rapid economic growth and raising the standard of living for its people (Anaduaka, 2014).

Keynes' EG ideas are used by Pesaran et al. (2001), who state that public spending is an example of an externality that fosters equitable growth. Government spending has been shown to be the main source of aggregate demand since it encourages sustainable growth. In this regard, Howitt and Aghion (1998) emphasized that the three main forces behind EG are labor, capital, and technological innovation, and that these forces are all connected to the utilization of energy as the main production method. Modern theory of education emphasizes that not only labor and capital factors contribute to the evolution of economic growth at various levels across economies, but that the quality of the labor factor itself is a critical factor influencing economic growth, in contrast to conventional theory (Fikri, 2025a). The analysis found empirical differences in the relationships between government spending, energy consumption, and economic growth. Keynes's EG approach was used to establish the theoretical framework for the current inquiry (Pesaran et al. 2001). Psacharopoulos and Patrinos (2018) assert that increased government expenditure speeds up production growth. The relationship between GGCS and EG is clearly caused by many pathways (Raihan and Voumik, 2022; Anaduaka, 2014). However, there were more differences in the link between GGCS and EG in the case of green energy. Public education initiatives that have the potential to increase technical innovation and productivity are responsible for Morocco's increasing rate of solarization. The goal of the current study is to ascertain how Morocco's economic growth is impacted by renewable energy (GGCS), education, artificial intelligence (AI), and health. This study collected annual data from 1993 to 2023 using the generalized linear model (GLM) and ARDL approaches in conjunction with WDI and ODCE (Almusallam et al., 2025).

From 2008 to 2021, Solow (1956) looked at the growth of the green economy, energy efficiency, and public research spending. Their findings indicate that to sustain a green economy through technology-driven industrial processes that provide several advantages, public support for R&D and human resources is crucial. Numerous studies have shown that energy use plays a significant role in accelerating environmental degradation (Raihan and Voumik, 2022). However, Yule (1926) used the model threshold to investigate the relationship between EG and REC in a sample of 103 countries. The findings demonstrated that employing renewable energy only helps to speed up EG after a specific threshold is achieved. Investments in renewable energy are crucial for the social and economic development of countries like Lebanon. Between 1990 and 2012, Zhang et al. (2021) discovered a favorable association between the use of REC and EG in Lebanon.

2.1. Research Gap

The years from 1993 to 2023 are a pivotal time in the evolution of the Moroccan economy. She begins after a decade of structural changes and continues into the modern day, which is characterized by globalization and sustainability demands. Over the past few years, Morocco has made significant changes, developed several sector-specific strategies (such as the Urgence Plan, Azur Plan, and strategic energy), and fostered the desire to invest in knowledge-based economies. The impact analysis of the four selected parameters helps to ascertain whether these investments and strategies have aided in economic development and to what extent they have prepared the nation to face the challenges of the twenty-first century. It's the first time that research studied the combination of these variables in this period and in the Moroccan context. So, there is not previous studies in Moroccan context gather theses variables in that time.

3. HYPOTHESES OF RESEARCH

A panesian cointegration study was applied to 24 OCDE nations between 1980 and 2006, according to Marques et al. (2019). According to their research, a 1% increase in REC in the energy mix raises PIB by 0.07 percent over the long run, with the effect being more pronounced in nations with stable energy policy. When REC's proportion of total REC surpasses 15%, its impact on growth only becomes considerable (+0.15% of PIB), according to Omri and Nguyen (2014), who applied the GMM approach to 64 nations (1990-2016). The quality of the institutions contributes to this effect. Dong et al. (2022) examine the impact of REC on EG in Energy Policy using a dynamic GMM model that was applied to 76 OECD and non-OECD nations between 2000 and 2019. Their results show that renewable energy sources boost growth more in developing nations (+0.21% PIB for 1% REC) than in rich ones (+0.12%) because they reduce dependency on fossil fuels. The study also shows that when REC makes up 32% of the energy mix, the best results are obtained. These results lend credence to the idea that, especially in emerging economies, the energy transition might act as a catalyst for EG. In the context of Southern Africa, Pfeiffer and Mulder (2013) demonstrate that investments in REC produce a "double dividend" by reducing pollution-related health expenses (1.2% of PIB) and directly stimulating PIB (+0.3%) using a DSGE model applied to southern Africa. Their analysis highlights how important targeted subsidies are. Ito et al. (2017) presented a spatial analysis covering 47 Asian nations between 1995 and 2014. The results demonstrate that the REC produced advantageous regional externalities: A 10% rise in a voisin country increases domestic development by 0.05% through technology transfers. So, our hypothesis is as follows:

H_1. The REC promotes economic growth.

However, Ahmad et al. (2023) use frontiers analysis in a study that covers 142 countries from 1990 to 2019 to demonstrate that the negative effect of public spending on growth is much more pronounced in developing countries (−0.21% growth per point

of PIB additional expenditures) than in developed countries (−0.08%). The PED's greater levels of corruption and poorer administrative efficiency, which worsen economic distortions, account for much of this disparity. The credibility of these results is confirmed by their model, which uses GMM to manage the endogeneity. The SVAR (1995-2018) model was used by Khan et al. (2021) to investigate the impact of growth limitations on the vertebrae (GGCS) in China. According to their research, a temporary modification to environmental laws results in a 0.3 percent decrease in the PIB, mostly because of private investment being retracted. But because of improvements in energy efficiency, the economy bounced back after 5 years. While showing that initial costs may eventually recover, this analysis emphasizes the tension governments face between short-term economic aims and climate change objectives.

H_2. GGCS impacts negatively on the EG.

On the other side, Asongu and Odhiambo (2020) assess how education affects growth in sub-Saharan Africa (SSA) and OCDE nations (2000-2018). They show that one extra year of schooling increases PIB/resident by 0.7% in SSA (because to the enhancement of human capital) and 0.3% in OCDE (due to innovation) using a DEA analysis and quantitative regressions. Additionally, the study demonstrates deteriorating outcomes beyond 12 years of education, underscoring the importance of adapting educational policy to developmental stages. These results show that education plays a significant role in growth, particularly in low-income nations. Africa's secondary education sector has contributed more to recent growth (12%) than physical capital (8%). Mensch et al. (2019), the 45-country study demonstrates how skill development has improved structural economic restructuring and continental connectivity. These results demonstrate the potential of human capital as a lever for growth in developing countries. Education appears to have a positive impact on EG, according to the advanced literature (World Bank, 2024).

H_3: Economic growth is positively impacted by education.

Most observers, including academics and practitioners, agree that artificial intelligence (AI) is the primary driver of the "third transformation of economic history," which follows the computer uprising of the 20th century and the IR of the 19th. In this regard, a survey on the implications of AI in a variety of disciplines was carried out in November and December 2021 by the ipsos organization, involving 19,504 individuals from 28 nations, ages 16 to 74. In the years ahead, respondents predict that AI will impact income 23%, security 33%, employment 32%, shopping 31%, transportation 30%, cost of living 26%, environment 22%, entertainment 27%, food 15%, education 35%, and interpersonal connections 15%. According to Acemoglu and Restrepo (2016), Hemous and Olsen (2014), Zeira (1998), and Aghion et al. (2017), artificial intelligence (AI) can increase growth by replacing labor, a limited resource, with capital, an infinite resource, in the production of commodities, services, and ideas. AI could, however, obstruct growth if it is combined with an unsuitable competitive policy. Artificial intelligence (AI) is the term used to describe a computer system that possesses human-like senses, cognition, and behavior.

H_4: AI has a good impact on EG.

4. METHODOLOGY AND DATA SOURCES

4.1. Justification of Choice of Variables

The foundation of human capital is education. This variable examines the ways in which increasing educational opportunities, raising the level of alphabetization, and improving the quality of instruction have boosted overall economic productivity. The key question is whether the Moroccan educational system has evolved into a productive force capable of meeting the demands of contemporary industries or if it continues to impede progress. More, the adoption of artificial intelligence as a critical factor can be explained by its ability to operate as a cross-cutting and productivity-boosting catalyst, which is essential for Morocco's future competitiveness. In a changing economic environment, artificial intelligence is more than just a standard technology; it acts as a strategic catalyst to enhance existing value chains and create new business models. Its impact is measured by reducing expenses and promoting innovation. Ultimately, in conjunction with other analysis factors, AI relies on a high-quality educational system to foster the necessary skills and directly contributes to expansion goals by enabling more efficient management of natural and energy resources. REC addresses a historical vulnerability of the Moroccan economy: energy dependence. Morocco, which imports more than 90% of its energy needs, was particularly affected by the volatility of fossil fuel prices, which had a detrimental effect on the country's economic balance and security. The rapid growth of renewable energy, as demonstrated by significant solar and eolian projects, has a direct impact on economic growth (EG) by lowering import costs, creating a new industry that attracts investment and jobs, and bolstering economic resilience. Renewable energy sources are not just an ecological necessity; they are also a key component of the modern growth strategy, which is inextricably linked to the goals of competitiveness and energy independence.

The variable GGCS was chosen strategically for this study since it represents the state's direct economic engagement. These expenditures, which directly support public services (such as health, education, and administration) and public investments, have a direct impact on global demand, employment, and living standards, hence promoting short-term growth. Additionally, within the framework of this study, they are crucial for analyzing the state's influence as an activator of other factors, which are typically public expenditures that launch large-scale REC projects, fund the educational system, and encourage an innovative environment around AI. Therefore, by analyzing the GGCS, it is possible to quantify the multiplicator effect of budgetary policies and assess the effectiveness of government intervention in Morocco's transition to a knowledge-based growth model. The choice of economic growth (EG) as a dependent variable, or the goal to explain, is driven by its status as the primary indicator of a country's development and progress. This study aims to assess the effectiveness of structural business reforms in Morocco by examining the growth of the GDP per capita from 1993 to 2023. The question is whether investments made in the fields of human capital (education), disruptive technologies (AI), REC, and GGCS have resulted in a notable increase in wealth creation. As a result, economic advancement serves as a worldwide indicator to assess the effectiveness of these tactics and represents the most important

Table 1: Data sources

Variables	Measurements	Data time	Source
Economic Growth	GDP (GDP per capita (Current US)	1993-2023	WDI
Education	School enrollment, primary, male (% gross) and School enrollment primary, female (% gross)	1993-2023	WDI
General Government Spending	General Government Consumption Spending (%GDP)	1993-2023	WDI
Artificial Intelligence	AI scientific publications time series by institution, from Scopus	1993-2023	ODCE
Renewable Energy Consumption	Renewable energy consumption (% of total final energy consumption)	1993-2023	WDI, Energy progress report, International Energy Agency (IEA)

Table 2: Descriptives statistic

Parametrs	Economic growth	REC	GGCS	Education female	Education male	AI
Mean	2582.875	14.66129	17.16092	95.30416	105.1355	54.00000
Median	3067.985	14.40000	17.22104	101.2530	110.5999	11.00000
Maximum	3785.936	22.40000	19.40499	113.0626	115.6308	346.0000
Minimum	1226.431	10.40000	14.30467	55.73833	78.06779	0.000000
Std. Dev.	869.8879	3.477708	1.332448	17.28548	10.89580	85.28814
Skewness	−0.247988	0.375150	−0.153821	−1.125659	−1.297763	1.906934
Kurtosis	1.424200	1.947938	2.009182	2.821104	3.254749	6.020597
Jarque-Bera	3.525136	2.156803	1.390304	6.588061	8.785467	30.57323
Probability	0.171604	0.340139	0.498999	0.037104	0.012367	0.000000
Sum	80069.13	454.5000	531.9885	2954.429	3259.202	1674.000
Sum Sq. Dev.	22701148	362.8335	53.26257	8963.637	3561.552	218222.0
Observations	31	31	31	31	31	31

factors for a sustainable development path. The Table 1 below gives the variables, measurements, data time, and source.

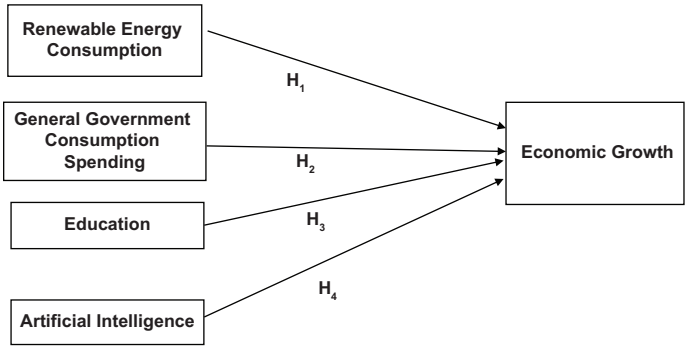
According to this conceptual model, the key variable to explain is Morocco's economic growth (or prosperity) between 1993 and 2023. It suggests that this growth is directly influenced by four key factors that act as independent but potentially complementary levers: education, which forms human capital; artificial intelligence, which innovates and increases productivity; renewable energy consumption, which ensures a sustainable energy transition; and public administration consumption spending, which represents the state's stimulus. The model's goal is to examine and quantify the specific effects of each of these variables on the nation's overall economic performance in order to determine the most effective development drivers (Figure 1).

Correlations between the LT long-term and ST short-term variables with varying integration orders are examined in this study using the ARDL. The ARDL outperforms earlier cointegration methods in three areas, according to Anaduaka (2014): (1) it works better with smaller data sets; (2) it can handle variables with different integration orders (I[1] or I[0]); and (3) it produces precise long-term forecasts. The Keynesian paradigm states that consistent economic growth is encouraged by rising government spending. The Cobb-Douglas production function is studied theoretically in this study. This is not the case, as the Pedroni model indicates that Y = f(K, L, S) represents the energy required for EG and that S is a productive energy. The following is the study model:

$$Y = f(REC, GGCS, AI, Education) \quad (1)$$

So,

Figure 1: Conceptual framework



$$GDP\ per\ capita_t = \alpha_0 + \alpha_1 REC_t + \alpha_2 GGCS_t + \alpha_3 AI_t + \alpha_4 Education_t + \varepsilon_t \quad (2)$$

In the Table 2 contains the following descriptive variables:

In the Table 2, the data show an average economic growth (EG) of 2582.875 accompanied by a considerable instability (Std. Dev. of 869.89), indicating a structural mutation phase. There has been a steady increase in both the use of renewable energy (REC) and public spending (GGCS), while men's education is statistically higher than women's. The equal diffusion of AI (1.91) attests to its recent and increasing acceptance, with extreme spots (maximum=346) that highlight its potential to cause disruption. Only the educational factors and the AI significantly exhibit a normal distribution, according to the normality analysis (Jarque-Bera). This suggests complex dynamics that call for specific economic models to determine their actual effects on EG.

Table 3: Stationary 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%)	
Economic growth	1.786303	−1.952473	0.9796	−5.816351	−1.952910	0.0000	-	-	-
Education female	0.557398	−1.952910	0.8307	−1.697164	−1.952910	0.0845	−5.104300	−1.953381	0.0000
Education male	1.017908	−1.952910	0.9146	−1.949149	−1.952910	0.0504	−5.154786	−1.953381	0.0000
GGCS	−0.112350	−1.952473	0.6367	−8.878588	−1.952910	0.0000	-	-	-
REC	−1.015768	−1.952473	0.2714	−4.855225	−1.952910	0.0000	-	-	-
AI	6.098019	−1.955020	1.0000	4.475822	−1.956406	1.0000	−2.498219	−1.953381	0.0145

Table 4: Number of lags

Number of lags	FPE	AIC	SIC	HQ
0	2.95e+11	43.43689	43.71978	43.52548
1	7589172	32.81119	34.79141*	33.43137*
2	7368688*	32.42884*	36.10639	33.58060

4.2. Unit Root

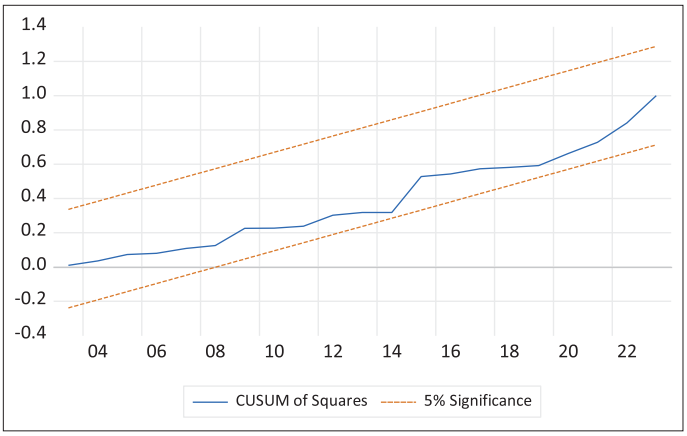
To determine whether a time series variable has a unit root and is non-stationary, a statistical procedure known as the unit root test is employed. A stochastic trend in a time series with a root value of one is called a unit root. In other words, a unit root process is one whose predicted value fluctuates greatly within a given range rather than remaining constant over time.

Most of the series (Economic growth, Education Female, Education Male, GGCS, REC, AI) exhibit in its raw state, but they acquire stationarity after a first differentiation, according to tests conducted to detect the presence of a unit root test. This attests to their inclusion in order I(1). The Artificial Intelligence (AI) data series is distinguished by its persistent non-stationarity up to the second differentiation, indicating an insertion of order I(2) that attests to its exponential and non-linear growth during this time. These findings support the employment of statistical methods tailored to non-stationary series, such as error-correction modeling, to prevent bogus regressions and reflect long-term relationships between the variables (Table 3). The unit root of the test can also be used to determine the integration order of the model variables. The test (ADF) is a well-known and useful control in this model that assesses the stationarity of the series.

To choose the best decalage to adopt, we used the information criteria AIC, SIC (BIC), and HQ. Analyses show that the criteria SIC and HQ point to a devaluation of 1, whereas the criteria AIC and FPE predict a devaluation of 2. In the current application, a decalage of 1 is typically preferred in order to preserve the degrees of freedom in medium-sized temporal series while maintaining the model as precise as possible. This choice ensures a balance between avoiding the stretchered of model parameters and capturing important temporal dynamics (Table 4).

The plot shows the cumulative change of the squares of the résidus (CUSUM of Squares) in relation to 5% confidence intervals. The trace remains completely localized in the criticized zones throughout the observation period (2004–2022), showing no signs of a significant deviation or rupture. This result highlights the stability of the model's parameters and the homoscedasticity of the

Figure 2: Cusum of squares



residuals during the whole period under analysis, demonstrating how reliable and respectable the assessments carried out to look at the factors influencing economic growth in Morocco are (Figure 2).

The graphs of the residuals for each variable in the model show generally good health, with no discernible trend or heteroscedastic structure. An appropriate model specification is indicated by an alpha variation of the residue around zero. However, periods of slight changes are observed, particularly in relation to the PIB by resident and scientific publications between 2010 and 2015, indicating either temporary external disturbances or a conditional variance that may be modelled. The lack of statistical correlation in these regressions validates the estimates and strengthens the validity of the established relationships between the explanatory factors and economic evolution (Figure 3).

All of the points are located inside the circle unit, according to the diagram of racines inverted from the polynomial characteristic linked to the representation AR of the VAR model. Given that no race is located on or outside of the unidirectional circle, this design attests to the stability of the estimated VAR model. This stability requirement is essential for guaranteeing the model's stationarity and the predictions' reliability, thereby validating the selection of the specification used to analyze the dynamic relationships between the variables under study (Figure 4).

In Table 5, with a determination value of R^2 of 0.976, the regression model demonstrates a high level of ability to explain. This shows that independent variables account for

Figure 3: VAR residuals

Figure 4: AR characteristic polynomial

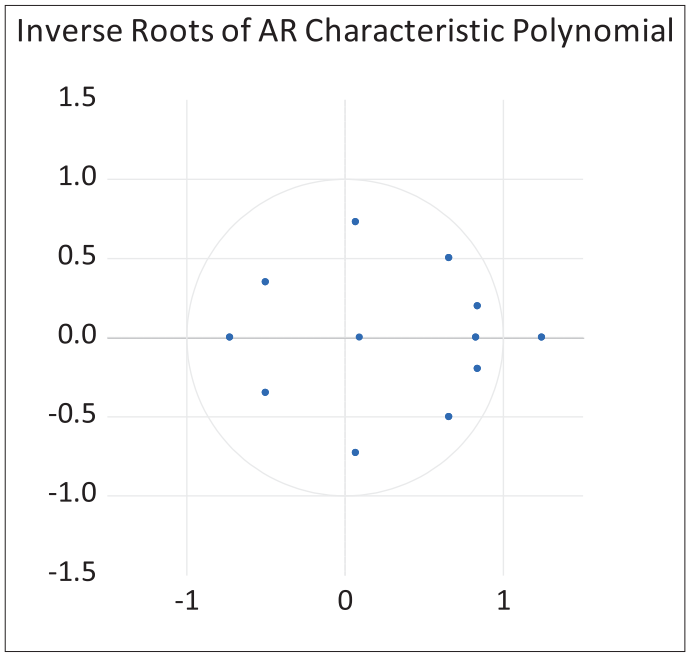


Table 5: Optimal model of ARDL

Variables	Coefficient	Std. Error	T-statistic	Prob.*
Economic growth (-1)	0.409236	0.163997	2.495387	0.0210
REC	−43.62954	19.18649	−2.273972	0.0336
GGCS	−110.6707	37.10509	−2.982629	0.0071
Education female	−63.61324	39.18250	−1.623512	0.1194
Education female (-1)	146.7576	34.96694	4.197040	0.0004
Education male	−34.75412	56.87730	−0.611037	0.5477
Education male (-1)	−76.11986	44.00244	−1.729901	0.0983
AI	1.152355	0.506481	2.275219	0.0335
C	7960.975	2712.107	2.935347	0.0079
R-squared	0.976317	Mean dependent var.		2628.090
Adjusted R-squared	0.967296	S.D. dependent var.		846.8985
S.E. of regression	153.1562	Akaike info criterion		13.14412
Sum squared resid	492593.5	Schwarz criterion		13.56448
Log likelihood	−188.1618	Hannan-Quinn criter		13.27860
F-statistic	108.2162	Durbin-Watson stat		2.167166
Prob (F-statistic)	0.000000			

97.6% of the fluctuations in economic growth. The value F (108,21), which indicates a probability of zero, attests to the model's general applicability. The Durbin-Watson test value of 2,167 indicates that there is no autocorrelation in the data, strengthening the estimators' credibility. The factors show a variety of influences: economic progress has a positive effect on current wealth (coefficient of 0.409), while renewable energy (REC) and government spending (GGCS) have significant negative effects that are likely caused by eviction or adjustment-related deceleration processes. And Artificial intelligence has demonstrated a significant positive impact (coefficient of 1.15), highlighting its significance as a technological catalyst for growth. Education sheds light on complicated temporal dynamics: Education female now is not conclusive, but a period of delay has a significant positive influence (146,75), highlighting the need of long-term educational investments. Education male appears to have little effect, which may indicate a misalignment with the demands of the labor market. These findings call for a review of public policies, particularly those pertaining to increasing government finances and renewable energy expenditures, as well as combining approaches to

women's education and IA integration. So, the optimal model is: ARDL(1,0,0,1,1,0).

In Table 6, the error correction model reveals a significant adjustment mechanism towards long-term equilibrium. The coefficient of correction of error (−0.59) linked to delayed economic growth is negative and statistically significant, confirming the presence of a cointegration relationship between the variables. This value of −0.59 indicates a relatively quick adjustment speed, with about 59% of the imbalance corrected annually. The variables REC, GGCS, and AI show significant coefficients in the long-term relationship with signs consistent with the regression standard: IA maintains its positive growth-promoting effect (1.15), while renewable energy (−43.63) and public spending (−110.67) maintain their unexpectedly negative effects, indicating short-term effects that may be hidden or structural issues in their implementation. A short-term study reveals many dynamics in the field of education. Long-term positive effects of investing in education female are significant (83.14), confirming the strategic importance of this investment in promoting economic growth. However, the short-term variations (D(Education Female)) and all the coefficients related to education male are not significant. These findings suggest that the educational dividend, particularly for women, is a long-term investment that has no discernible immediate effects. This makes it clear to political leaders how important it is to continue vigorous educational initiatives, particularly for women, while also reevaluating the relevance and quality of trainings, particularly for men, to maximize their impact on economic growth.

Long-term coefficient evaluation reveals significant yet contradictory structural relationships. With a positive note of 1.95, artificial intelligence is confirmed as a growth factor, demonstrating that increased use strongly supports long-term economic growth. Additionally, women's education turns out to be a significant long-term development drive (with a coefficient of 140.74). However, renewable energy (−73.85) and public spending (−187.33) show unanticipated negative effects, suggesting that their funding or application mechanisms may result in eviction effects or structural inefficiencies. The negative impact of masculine education is −187.68, raising concerns about how well the skills required in the labor market match the education provided. This highlights the need for a dramatic overhaul of the educational system to translate human capital into actual economic development (Table 7).

The obtained value F of 5.54 exceeds all the critical seuils at 1% for the I(1) series, which are 3.06 (lower limit) and 4.15 (upper limit), respectively. This result leads us to reject the null hypothesis, which holds that there is no long-term link between cointegration and other factors, with great confidence. This is the lower bound of the 10% threshold for determining the long-term relationship. Since the F-statistic equals 5.535861, which is higher than all the values in the table among them (2.08), this indicates that there is such a relationship. Therefore, it has been statistically demonstrated that there is a steady and significant long-term relationship between Morocco's economic growth and all explanatory variables (Table 8).

Table 6: Short run

Conditional error correction regression				
Variable	**Coefficient**	**Standard error**	**t-statistic**	**Prob.**
C	7960.975	2712.107	2.935347	0.0079
Economic Growth (-1)*	−0.590764	0.163997	−3.602284	0.0017
REC**	−43.62954	19.18649	−2.273972	0.0336
GGCS**	−110.6707	37.10509	−2.982629	0.0071
Education female (-1)	83.14438	38.83354	2.141046	0.0442
Education male (-1)	−110.8740	55.02680	−2.014909	0.0569
AI**	1.152355	0.506481	2.275219	0.0335
D (Education Female)	−63.61324	39.18250	−1.623512	0.1194
D (Education Male)	−34.75412	56.87730	−0.611037	0.5477

Table 7: Long run

Variable	**Coefficient**	**Standard error**	**t-statistic**	**Prob.**
REC	−73.85275	27.74567	−2.661775	0.0146
GGCS	−187.3349	80.90623	−2.315457	0.0308
Education female	140.7404	49.04589	2.869567	0.0092
Education male	−187.6790	71.96470	−2.607931	0.0164
AI	1.950619	0.885003	2.204082	0.0388
C	13475.73	3477.043	3.875629	0.0009

Table 8: Bound test

Test statistic	**Value**	**Significant**	**I (0)**	**I (1)**
			Asymptotic: n=1000	
F-statistic	5.535861	10%	**2.08**	**3**
k	5	5%	**2.39**	**3.38**
		2.5%	**2.7**	**3.73**
		1%	**3.06**	**4.15**

Table 9: Quantile regression

Variable	**Coefficient**	**Standard error**	**t-Statistic**	**Prob.**
REC	−49.70866	39.25277	−1.266373	0.2171
GGCS	−53.74990	75.92231	−0.707959	0.4855
Education female	136.4892	80.92564	1.686600	0.1041
Education male	−161.8170	121.1783	−1.335363	0.1938
AI	1.187397	1.042683	1.138790	0.2656
C	8259.241	5158.872	1.600978	0.1219
Pseudo R-squared	0.754263	Mean dependent var		2582.875
Adjusted R-squared	0.705116	S.D. dependent var		869.8879
S.E. of regression	331.5875	Objective		2938.462
Quantile dependent var	3067.985	Restr. objective		11957.77
Sparsity	773.1138	Quasi-LR statistic		93.32967
Prob (Quasi-LR stat)	0.000000			

4.3. Quantile Regression

With an important pseudo-R-value of 0.75, the evaluation using the median approach of quantiles reveals structural relationships that are different from those established using the smallest squares. Even while none of the variables reach the typical statistical significance level of 5%, some show noteworthy effects. Women's education has a significant positive coefficient (136,49), highlighting its potential as a growth engine, whereas

men's education continues to have a noticeable negative effect (−161,82). While renewable energy and government spending continue to show negative coefficients, even if they are not statistically significant, the positive influence of artificial intelligence (1,19) remains. Global insignificance implies that the components of Morocco's economic growth operate differently depending on economic performance phases, necessitating a more thorough examination of growth regimes (Table 9).

5. DISCUSSION

The findings of Acemoglu et al. (2022), Aghion et al. (2017), Acemoglu and Restrepo (2016), Hemous and Olsen (2014), and Zeira (1998) are therefore consistent with our findings. While the development of AI boosts confidence for consumer spending, increases productivity across most industries, and improves risk management, it also raises concerns about the substantial loss of jobs in developed nations, the need for a general reduction in talent, and the escalation of the numerical divide within social constructions. Because EG is negatively impacted in the short term by an abrupt increase of AI publications. This is intriguing that temporarily reduce profitability before they pay off. Additionally, there is a delay in the commercial or industrial adoption of scientific articles due to the maturation process. Thus, hypothesis 4 has been validated. However, our findings also supported the findings of Mensch et al. (2019), confirming hypothesis 3. Regarding hypothesis 2, our results concurred with Khan et al. (2021) that GGCS slow economic growth, necessitating greater government focus on consumer spending. Thus, our study's hypotheses have been validated. But, in Moroccan context, the hypothesis 1 has been rejected depends on some reasons:

- Massive governmental and private investments are required for the swift and ambitious development of renewable energy infrastructure, such as the Noor solar complex in Ouarzazate. These resources, which are typically gathered through government intervention or a publicly owned resource, may have been diverted from more short-term, directly productive economic sectors like manufacturing or services. Furthermore, a sizeable amount of these investments went toward importing advanced technology and equipment, which may have had a short-term negative effect on the commercial balance without directly boosting domestic industrial production.
- The economic benefits of renewable energy sources, such as lower energy costs, assurance of supply, and the development of a local industrial sector, are substantial and fully manifest over the medium and long term. Examining the years 1993–2023 clearly demonstrates this transition's period of high capital intensity, when expenses are high and profits are mostly unrealized. Quantified economic expansion (PIB) does not immediately translate these future gains and this increase in energy resilience.
- Notwithstanding its environmental benefits, renewable energy production requires less work than conventional sectors. There may be a short-term effect on employment and overall value added if the growth of the vertebral filament is insufficient to offset losses or losses in the traditional energy sectors. Additionally, intermittent issues or adjustments to the electrical network may initially prevent the competitive benefits that industrial societies expect.

6. CONCLUSION

With a focus on education, artificial intelligence, renewable energy, and government spending, this study helped analyze the factors influencing Morocco's economic growth during a 30-year period. The findings show complex and contradictory relationships. Artificial intelligence and women's education (with some retardation) have been shown to be significant positive factors, highlighting the value of human capital and technological innovation. However, the negative impact of renewable energy and public spending suggests that its funding and implementation may result in short-term eviction consequences, negating their long-term benefits. The ambiguity surrounding male education raises questions about how training and employment align. Overall, the study confirms the validity of the selected theoretical model by demonstrating the presence of a long-term relationship of equilibrium between these variables.

This research has several limitations of its own. The main problem is the aggregated nature of macroeconomic data, which can represent different sectoral or regional dynamics. Even if the analysis period is long, it includes a specific transitional phase that may explain the unexpected results, especially when it comes to renewable energy. Furthermore, even though they are frequently used, the evaluation of some variables, like the AI, by the number of publications does not always indicate their actual use and productivity within the economy. Ultimately, even with the use of sound economic techniques, the possibility of missing variables or persistent endogeneity cannot be eliminated. This work opens up a number of possibilities for further research. A sector-by-sector analysis would make it easier to identify the precise pathways through which AI and renewable energy sources affect productivity. Additionally, it would be beneficial to base the analysis of education's impact on qualitative indicators (education quality, skill relevance) rather than quantitative indicators connected to scalarization rate. The use of methods that allow for a more accurate identification of causalities, such as structural equation models or instrumental variables, would be a significant methodological advancement. Finally, a comparative analysis with other emerging countries that have undergone similar changes would have helped to contextualize and standardize the findings observed in Morocco.

The findings of this study encourage a review of national development strategies. They anticipate a cumulative investment focused on educating children and spreading AI, which have been identified as growth-promoting factors. In the case of renewable energy, policies should focus on local industrial integration and related professional training to maximize economic returns while minimizing short-term eviction implications. The negative correlation with public spending suggests that their distribution and effectiveness need to be improved. Ultimately, a comprehensive overhaul of the educational system, including for men, is necessary to better tailor the training offered to the demands of a digital and tech-oriented economy.

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