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Article

Macroeconomic determinants of education level: Evidence from selected African oil-exporting countries

Talent Thebe Zwane*, Akindele John Ogunsola

School of Economics, College of Business and Economics, University of Johannesburg, Johannesburg 2092, South Africa
*** Corresponding author:** Talent Thebe Zwane, ttzwane@uj.ac.za

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Abstract: This study examines the relationship between macroeconomic determinants and education levels in eight selected African oil-exporting countries (AOECs) over the period 2000–2022. Drawing on human capital theory, the paper scrutinizes the impact of factors such as income inequality, health outcome, economic growth, human development, unemployment, education expenditure, institutional quality, and energy consumption on education levels. Employing robust estimation techniques such as fixed effects (FE), random effects (RE), pooled mean group (PMG) and cross-section autoregressive distributed lag model (CS-ARDL), the study unveils vital static and dynamic interactions among these determinants and education levels. Findings reveal notable positive and significant connections between education levels and some of the variables—human capital development, institutional quality, government expenditure on education, and energy consumption, while income inequality demonstrates a consistent negative relationship. Unexpectedly, health outcomes exhibit a negative impact on education levels, warranting further investigation. Furthermore, the analysis deepens understanding of long-run and short-run relationships, highlighting, for example, the contradictory impact of gross domestic product (GDP) and unemployment on education levels in AOECs. Finally, the study recommends targeted human development programs, enhanced public investment in education, institutional reforms for good governance, and sustainable energy infrastructure development.

Keywords: human development; energy; health; income inequality; education level; AOECs
JEL Classification: E21; E24; P36; Q43

1. Introduction

Higher education is vital for economic growth and human capital development. Governments worldwide prioritize its expansion, yet disparities persist, notably in African oil-exporting countries (AOECs) (Batool and Liu, 2021). People from disadvantaged backgrounds encounter hurdles despite academic competence, leading to socioeconomic constraints. Likewise, education and work experience correlate positively with higher incomes, especially in developing nations, where primary education investment yields significant social returns over tertiary education (Mulliqi et al., 2019; Osiobe, 2019). Education not only boosts income but also reduces poverty by enhancing quality of life through human development (HDI), thereby addressing multifaceted issues exacerbated by macroeconomic instability (Imeokparia et al., 2023; UNDP, 2019). Despite compulsory basic education in AOECs, affordability challenges hinder access to higher education and employment opportunities. Improving education accessibility is crucial for poverty alleviation and enhancing living standards (Gumede and Biyase, 2016). This emphasizes the importance of strategic policy in educational investment for human capital development, income growth, and poverty reduction.

Africa's emphasis on education levels has been shifting towards enhancing educational efficiency through comprehensive development strategies. Investment in education that is crucial for economic growth faces challenges in AOECs due to corruption and weak governance (Ali and Mahmoud, 2022; Raifu et al., 2021). Consequently, policymakers have stressed the important of promoting institutional quality to ensure effective educational performance (Asongu and Odhiambo, 2020). However, despite recommendations like the Dakar Framework, AOECs are still struggling to meet their yearly education budget targets due to misallocation of resources and bureaucracy that results in weak institutional quality. Furthermore, while education is linked with economic growth, its impact on income distribution remains uncertain. Knight and Sabot (1983) outline opposing effects of education expansion on inequality, supported by recent studies of Moyo et al. (2022) and Ferreira et al. (2022), contradicting the findings from the study of Rafiu et al. (2021), which confirmed positive relationship.

Promoting education alongside energy initiatives in oil-exporting nations could enhance global literacy rates, which vary across African countries. Education influences energy consumption, affecting different sustainability strategies based on developmental stages (Inglesi-Lotz and Morales, 2017; Sart et al., 2022). However, inadequate access to clean energy poses risks, particularly in developing regions, hindering education and employment, especially for women, impacting overall well-being in AOECs (Igawa and Managi, 2022). Likewise, poor health, due to factors like disease, malnutrition, and inadequate healthcare access, can disrupt schooling through absenteeism and diminished learning capacity. Consequently, higher education levels correlate with better health outcomes, as educated individuals are more likely to adopt healthier behaviors and access healthcare services (Eggoh, et al., 2015). Hence, good health can enhance educational level by mitigating health-related barriers to learning.

Notwithstanding, AOECs have struggled with human capital development over the years, marked by poor education and healthcare infrastructures despite abundant resources. This hampers economic growth and exacerbates unemployment (Njifen, 2024). Moreover, despite extensive studies on the relationship between macroeconomic factors and education, significant gaps remain in understanding how these dynamics play out in AOECs. Studies like Harsono et al. (2024) and Asongu et al. (2023) provide valuable insights into income distribution and governance but overlook the unique economic structures and policy environments in AOECs. Additionally, Njifen (2024) focuses on unemployment's impact on education but fails to address the nuanced role of human development in shaping educational outcomes in AOECs. Against this backdrop, this paper addresses these gaps by investigating how macroeconomic determinants specific to AOECs influence education levels, thereby contributing to a more contextual understanding of education policy and economic development in these regions.

Furthermore, this study advances existing literature by incorporating a broader set of macroeconomic determinants such as income inequality, health outcomes, economic growth, human development, unemployment, education expenditure, institutional quality, and energy consumption than previous studies. These extended variables were selected based on their relevance to the unique economic and social structures of AOECs, where fluctuations in oil revenue and weak institutional frameworks can significantly influence educational levels. The inclusion of these diverse variables provides a more comprehensive explanation of the research problem by capturing the multifaceted interactions between economic stability, governance, and education levels in these regions. While this study focuses on direct relationships, future research could explore the interaction effects of these variables, especially in understanding the compounded impact of institutional quality and energy consumption on education levels.

Overall, this paper comprises five distinct sections. The preceding section provides the introduction, the second section provides an examination of pertinent literature, while sections three and four concentrate on delineating the research methodology and conducting analysis and interpreting empirical findings, respectively. Finally, section five encompasses the conclusion and offers policy recommendations.

2. Literature review

The relationship between macroeconomic determinants and education levels in AOECs is crucial for fostering human capital development and economic growth, as illustrated in **Figure 1**. While economic prosperity enhances educational opportunities, resource-rich nations may face obstacles due to the "resource curse" (Auty, 1995). Poverty, unemployment, and income disparity hinder education access, perpetuating social inequalities (Arezki and Brückner, 2021). Health outcomes, influenced by healthcare access, impacts attendance and cognitive development in education, while direct investment in education expenditure improves educational infrastructure and teacher quality, contingent upon institutional integrity, with corruption undermining the effectiveness of education levels (Adejumo et al., 2021). Finally, energy consumption is essential for educational activities and socioeconomic progress, aiding improvement in learning.

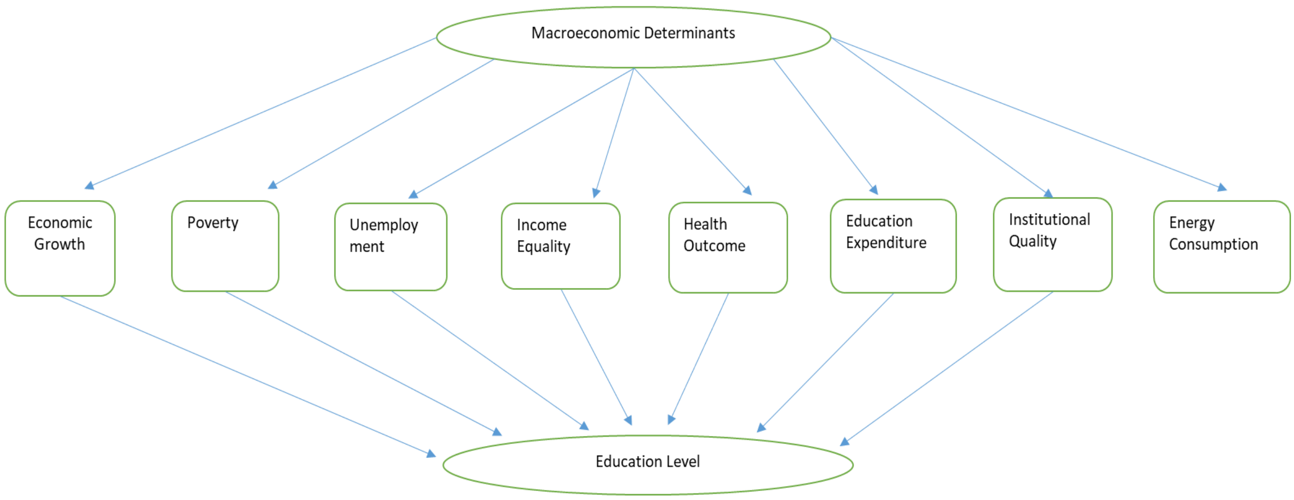

Figure 1. Macroeconomic determinants and education level.

Source: Authors' compilations (2024).

Thus, this review presents key questions for further investigation: How do macroeconomic factors, particularly GDP and unemployment affect the educational level in AOECs? What is the part played by human development, governance, health outcome, and education expenditure on education in these countries? How do changes in energy consumption and income inequality influence access to and quality of education in these nations? The hypotheses are that changes in energy consumption and income inequality lower educational levels, efficient human development, strong governance, good health outcomes, and increased education spending can reduce the negative impacts of energy consumption and income inequality on education levels, and macroeconomic factors including low GDP and increased unemployment have greatly limited access to and quality of schooling.

Empirical studies, including Harsono et al. (2024), illuminate complex relationships among macroeconomic factors, health, education, and social inequality. Their quantitative analysis in West Papua highlights strong negative links between income distribution, poverty rates, and health disparities, emphasizing economic factors' pivotal role. Additionally, Njifen (2024) explores the inverse relationship between youth unemployment and higher education enrollment in Sub-Saharan Africa (SSA), indicating a potential for addressing unemployment to improve higher education outcomes, particularly in low human development countries.

Hailat and Magableh (2024) studied household socio-economic factors' influence on education in Jordan pre- and post-refugee influx, noting no direct negative impact on Jordanians in refugee host areas despite declining enrollment. Ngepah et al. (2023) highlight a significant inverse relationship between education and poverty vulnerability in South Africa, stressing the need for educational quality improvement to combat poverty and enhance global employability, urging policymakers to prioritize educational reforms.

Asongu et al. (2023) extend the exploration to SSA countries, examining income inequality thresholds that nullify governance dynamics' positive impact on gender-inclusive education. Governance consistently shows positive unconditional effects on inclusive education, but negative conditional effects when interacting with inequality. Likewise, Ali and Mahmoud (2022) focus on Asian and North African countries, finding that efficient education positively impacts economic growth, with Asian countries demonstrating higher efficiency and economic development compared to North African nations.

Koh et al. (2022) examine nineteen Asian economies, finding that while educational level widens inequality, trade openness, and institutional quality mitigate income inequality in the Asia-Pacific. Raifu et al. (2021) demonstrate the significant role of female education in Nigeria's economic growth. Liu et al. (2021) stress higher education's critical role in poverty reduction in developing economies. Jellenz et al. (2020) affirm the link between tertiary education and economic progress in Namibia, emphasizing education's role in sustainable growth.

Arguments to previous studies, income inequality and unemployment limit access to quality education, perpetuating social inequalities. Health and human development are key factors, with access to healthcare and education directly impacting school attendance and cognitive development. Investment in education infrastructure, contingent on governance and institutional quality, enhances educational outcomes, but corruption can undermine these efforts. Furthermore, energy consumption is crucial for both educational activities and broader socioeconomic progress. By considering these variables, this study captures a more comprehensive picture of the multifaceted nexus among macroeconomic determinants, governance, and education in AOECs, filling a gap in previous scanty studies that tend to isolate these factors.

Finally, while studies like those of Harsono et al. (2024) and Njifen (2024) examine the impact of income distribution and unemployment on education, they do not fully account for the unique challenges faced by AOECs, where the volatility of oil revenues and institutional weaknesses have a significant influence on education outcomes. Moreover, Osiobe (2019) highlight the role of education expenditure, but they overlook how governance issues, energy consumption, and income inequality particularly in resource-rich countries, can dilute the effectiveness of such investments in education. Lastly, while previous works have considered the direct effects of macroeconomic determinants such as inflation, exchange rate, and interest rate, they have not fully explored critical macroeconomic issues of high unemployment and weak human development in influencing education.

3. Methodology

3.1. Theoretical framework and model specification

This study draws from human capital theory, which highlights the role of education in enhancing productivity and economic growth. As proposed by Schultz (1961), investments in education, healthcare, and training are seen as crucial to human capital development. According to Becker (2009), such investments lead to higher individual productivity, which in turn fosters economic growth. This framework supports the idea that macroeconomic factors such as income levels, human development, and health outcomes have direct effects on educational levels. Moreover, Mincer (1974) emphasizes the relationship between years of schooling and wages, suggesting that education directly influences earning potential. Although this study does not estimate specific wage-related models, this theoretical background provides a foundation for exploring the impact of macroeconomic factors on education levels.

In the context of AOECs, this study expands the human capital framework by integrating additional determinants, such as institutional quality and energy consumption, which are particularly relevant to the unique socioeconomic conditions in these nations. Building upon the theoretical framework, the empirical analysis employs a modified version of Barro and Sala-I-Martin's (2004) cross-country growth equation. The core econometric model to estimates the relationship between education levels and selected macroeconomic determinants in eight African oil-exporting countries over the period from 1990 to 2022 is specified as follows:

$$\mathrm{EDU}_{\mathrm{it}} = \beta_{i,0} + \beta_{i,1}\mathrm{GDP}_{i,t} + \beta_{i,2}\mathrm{HDI}_{i,t} + \beta_{i,3}\mathrm{UMP}_{i,t} + \beta_{i,4}\mathrm{IEQ}_{i,t} + \beta_{i,5}\mathrm{HEA}_{i,t} + \beta_{i,6}\mathrm{EED}_{i,t} + \beta_{i,7}\mathrm{INQ}_{i,t} + \beta_{i,8}\mathrm{ENER}_{i,t} + \varepsilon_{i,t} \tag{1}$$

where:

EDU = Education levels

GDP = Gross domestic product
HDI = Human development index
UMP = Unemployment rate
IEQ = Income inequality
HEA = Health outcomes
EED = Education expenditure
INQ = Institutional quality
ENER = Energy consumption
β's = Unknown parameter estimates
i = Eight selected African oil-exporting countries
t = Time period (1990–2022)
ε = Stochastic error term

This model captures the influence of various macro and socio-economic determinants on educational levels, recognizing that fluctuations in oil revenues and institutional quality are particularly critical for AOECs. Through robust estimations, this study seeks to understand how these determinants collectively shape education levels in these countries over time.

Furthermore, it is anticipated that:

- Economic Growth (GDP): Education typically improves as GDP rises, as increased economic growth provides more resources for education funding (Barro and Sala-i-Martin, 2004). Thus, $\frac{\partial(EDU)}{\partial(GDP)} > 0$.
- Human Development Index (HDI): Enhancing human development generally promotes access to education by increasing the ability to attend school due to the improvement in quality of life and education (Jellenz et al., 2020). Hence, $\frac{\partial(EDU)}{\partial(HDI)} > 0$.
- Unemployment (UMP): High unemployment often discourages investment in education, as the perceived return on education diminishes (Njifen, 2024). Thus, $\frac{\partial(EDU)}{\partial(UMP)} < 0$.
- Income Inequality (IEQ): Greater inequality tends to limit access to education, especially for disadvantaged groups (Asongu et al., 2023), resulting in $\frac{\partial(EDU)}{\partial(IEQ)} < 0$.
- Health (HEA): Improved health positively influences education by enhancing cognitive abilities and reducing absenteeism (Harsono, et al., 2024), leading to $\frac{\partial(EDU)}{\partial(HEA)} > 0$.
- Education Expenditure (EED): Increased spending on education directly improves educational infrastructure and quality (Eggoh et al., 2015), so $\frac{\partial(EDU)}{\partial(EED)} > 0$.
- Institutional Quality (INQ): Strong institutions promote better education outcomes by ensuring effective governance and reducing corruption (Asongu et al., 2020), resulting in $\frac{\partial(EDU)}{\partial(INQ)} > 0$.

- Energy Consumption (ENER): Adequate energy infrastructure supports educational activities, particularly in schools and universities (Sart et al., 2022), hence $\frac{\partial(EDU)}{\partial(ENER)} > 0$.

3.2. Data, justification and measurements of variables

Due to the constraints imposed by data availability, the paper's scope was defined focusing on eight African nations known for exporting oil. The study period spans 23 years, from 2000 to 2022. Specifically, the countries included are Algeria, Angola, Congo, Equatorial Guinea, Gabon, Egypt, Libya, and Nigeria. These countries were selected due to their significant reliance on oil exports and the unique macroeconomic challenges they face, including the resource curse, which can impact educational outcomes.

The macroeconomic variables were specifically selected to be relevant to the economic and social dynamics of AOECs. The variables were prioritized due to their strong theoretical and empirical links with levels of education especially in resource-rich economies. For instance, economic growth (GDP) and human development (HDI) are major driving forces behind educational investments and infrastructure development while Unemployment (UMP) signify the financial hardships that can affect accessibility to education. In addition, Income Inequality is responsible for capturing the distributional aspects that are likely to influence educational equity. Since good governance has a considerable effect on how resources are distributed for educational purposes it can help to alleviate or aggravate the effects of resource curse. Furthermore, Energy Consumption (ENER) is vital in this context as energy availability affects the delivery of education particularly in rural and marginalized regions.

To gather information, the data for this study were retrieved from the World Development Indicators (WDI), United Nation Development Programme (UNDP), Worldwide Governance Indicators (WGI), US Energy Information Administration (EIA), and World Inequality Database (WID). Consequently, the variables, measurements, and sources of data collection were detailed in **Table 1**.

Table 1. Variables, measures and sources.

Variable	Measure	Code	Source
Education level	Educational levels via average years of schooling enrolment.	EDU	UNDP
Economic growth	Real GDP per capita growth (annual %)	GDP	WDI
Human development	Human development index (value).	HDI	UNDP
Unemployment	Unemployment, total (% of total labor force) (ILO).	UMP	WDI
Income inequality	Pre-tax national income (Gini coefficient—adult population equal split).	IEQ	WID
Health outcome	Domestic general government health expenditure (% of current health expenditure).	HEA	WDI
Education expenditure	Government expenditure on education (% of total government expenditure).	EED	WDI
Institutional quality	Average of worldwide governance indicators (computable).	INQ	WGI
Energy Consumption	Total energy consumption (quad Btu)	ENER	EIA

Source: Authors' compilations (Institutional Quality (INQ) is calculated by the average estimates of the Worldwide Governance Indicators (WGI) which consist control of corruption, government effectiveness, political stability and absence of violence/terrorism, regulatory quality, rule of law, and voice and accountability).

3.3. Estimation strategies

3.3.1. Slope homogeneity test

Swamy (1970) introduced a method to assess slope coefficient homogeneity. Pesaran and Yamagata (2008) enhanced this test, creating two "delta" statistics namely: $\check{\Delta}$ and $\widetilde{\Delta_{adJ}}$.

$$\check{\Delta} = \sqrt{N}\left(\frac{N^{-1}S - k}{\sqrt{2k}}\right) \sim X_k^2 \tag{2}$$

$$\widetilde{\Delta_{adJ}} = \sqrt{N}\left(\frac{N^{-1}S - k}{v(T,k)}\right) \sim N(0,1) \tag{3}$$

For N cross-section units, Swamy (1970) test (S) with k independent variables determines homogeneity. The null hypothesis is accepted if p > 5%, implying homogeneous cointegrating coefficients. Delta test (Δ) is adapted for large/small samples (Δ_{adj}), while Pesaran and Yamagata (2008) and Blomquist and Westerlund (2013) developed a robust HAC version:

$$\widetilde{\Delta_{HAC}} = \sqrt{N}\left(\frac{N^{-1}S_{HAC} - k}{\sqrt{2k}}\right) \sim X_k^2 \check{\Delta} = \sqrt{N}\left(\frac{N^{-1}S - k}{\sqrt{2k}}\right) \sim X_k^2 \tag{4}$$

$$(\widetilde{\Delta_{HAC}})adJ = \sqrt{N}\left(\frac{N^{-1}S_{HAC} - k}{v(T,k)}\right) \sim N(0,1) \tag{5}$$

If all p-values are below 0.05, rejecting the null hypothesis indicates non-homogeneous slope coefficients, implying heterogeneity among sample countries, and requiring heterogeneous panel techniques.

3.3.2. Cross-sectional dependence tests

Chudik and Pesaran (2015) CD tests detect cross-dependency among selected variables by scrutinizing residual cross-sectional dependence.

$$CD_{NT}^{2015} = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \frac{1}{\sqrt{T}} \sum_{t=1}^{T} \varepsilon_{it}\, \varepsilon_j \tag{6}$$

$$CD_{BKP} = \sqrt{\frac{TN(N-1)}{2}}\, \rho_N \tag{7}$$

Statistically significant 5% tests validate cross-sectional dependence assumption in model residuals. Building on Bailey et al. (2019), the analysis extends to estimate cross-sectional dependence statistics for relevant variables (EDU, GDP, HDI, UMP, IEQ, HEA, EED, INQ, ENER).

3.3.3. Second generation unit root test

To detect stationarity with cross-sectional dependence, second-generation unit root tests are applied. Strong cross-sectional dependence in residuals (and in variables) will prompt the use of these tests, as the first-generation tests do not address such dependence (Im et al., 2003). Pesaran (2007) second-generation unit root tests were employed for analysis. Mathematically:

$$\Delta Y_{i,t} = a_i + b_i Y_{i,t-1} + c_i Y_{t-1} + d_i Y_t + \varepsilon_{i,t} \tag{8}$$

With a_i as a deterministic term, Y_t as the cross-sectional mean at time *t*, and ρ as the lag order, t_i (*N*, *T*) represents the *t* ratio of α_i, known as cross-sectional Augmented Dickey-Fuller (CADF) attributed to Pesaran (2007). The average of these *t* ratios yields the cross-sectional IPS (CIPS), and these tests will be estimated with a constant and trend term at the level and first difference.

3.3.4. Techniques of analyses

Static analysis

To explore the empirical connection between macroeconomic determinants and education levels in African nations reliant on oil exports, we performed the following analyses. Our approach involves estimating static models that do not incorporate any lagged dependence on the dependent variable. These models encompass:

Pooled OLS:

$$EDU_{it} = \alpha_i + \beta_{i,1}GDP_{i,t} + \beta_{i,2}HDI_{i,t} + \beta_{i,3}UMP_{i,t} + \beta_{i,4}IEQ_{i,t} + \beta_{i,5}HEA_{i,t} + \beta_{i,6}EED_{i,t} + \beta_{i,7}INQ_{i,t} + \beta_{i,8}ENER_{i,t} + \varepsilon_{i,t} \tag{9}$$

Fixed Effects:

$$EDU_{it} = \alpha_i + \beta_{i,1}GDP`_{i,t} + \beta_{i,2}HDI`_{i,t} + \beta_{i,3}UMP`_{i,t} + \beta_{i,4}IEQ`_{i,t} + \beta_{i,5}HEA`_{i,t} + \beta_{i,6}EED`_{i,t} + \beta_{i,7}INQ`_{i,t} + \beta_{i,8}ENER`_{i,t} + \varepsilon_{i,t} \tag{10}$$

Random Effects:

$$EDU_{it} = \alpha_i + \beta_{i,1}GDP`_{i,t} + \beta_{i,2}HDI`_{i,t} + \beta_{i,3}UMP`_{i,t} + \beta_{i,4}IEQ`_{i,t} + \beta_{i,5}HEA`_{i,t} + \beta_{i,6}EED`_{i,t} + \beta_{i,7}INQ`_{i,t} + \beta_{i,8}ENER`_{i,t} + \beta_0 + \varepsilon_{i,t} \tag{11}$$

First Differenced Fixed Effect:

$$EDU_{it} = \alpha_i + \beta_{i,1}\Delta GDP`_{i,t} + \beta_{i,2}\Delta HDI`_{i,t} + \beta_{i,3}\Delta UMP`_{i,t} + \beta_{i,4}\Delta IEQ`_{i,t} + \beta_{i,5}\Delta HEA`_{i,t} + \beta_{i,6}\Delta EED`_{i,t} + \beta_{i,7}\Delta INQ`_{i,t} + \beta_{i,8}\Delta ENER`_{i,t} + \varepsilon_{i,t} \tag{12}$$

Dynamic analysis

Augmented autoregressive distributed lag model:

After assessing variable stationarity, the study applies the ARDL (*p*, *q*) model in error correction, utilizing two estimators: pooled mean group (PMG) and cross-section autoregressive distributed lag (CS-ARDL). The choice of the PMG and CS-ARDL estimators were guided by their robustness in handling heterogeneous panels and their ability to capture both short- and long-term effects, as demonstrated by Pesaran and Smith (1995). The PMG model, in particular, is suitable for estimating long-run relationships while allowing short-run dynamics to vary across countries, making it ideal for the diverse economies in the sample. Thus, the general PMG formulation is given as:

$$\Delta(Y_i)_t = \sum_{j=1}^{p-1} Y_j^i \Delta(Y_i)_{t-j} + \sum_{j=0}^{q-1} \delta_j^i \Delta(X_i)_{t-j} + \varphi^i [(Y_i)_{t-1} - \{\beta_0^i + \beta_1^i (X_i)_{t-1}\}]\epsilon_{it} \tag{13}$$

Furthermore, the CS-ARDL model attributed to Chudik and Pesaran (2015) is given as:

$$D_{i,t} = \sum_{I=0}^{PD} \vartheta_{I,i} D_{i,t-I} + \sum_{I=0}^{PX} \delta_{I,i} X_{i,t-I} + \epsilon_{i,t} \quad (14)$$

Addressing cross-sectional dependency and slope heterogeneity, the extended equation is provided as:

$$D_{i,t} = \sum_{I=0}^{PD} \vartheta_{I,i} W_{i,t-I} + \sum_{I=0}^{PX} \delta_{I,i} X_{i,t-I} + \sum_{I=0}^{PZ} \sigma_i I Z_{t-I} + \epsilon_{i,t} \quad (15)$$

In equation (15), $Z_{t-1} = D_{i,\,t}$, $X_{i,\,t}$ which provides the average. Moreover, PD, PX, and PZ are the lags value. $D_{i,t}$ is the dependent variable, while $X_{i,\,t}$ are independent variables.

Consequently, the long run estimates are given as:

$$\theta_{CS-ARDL,i} = \frac{\sum_{I=0}^{PX} \delta_{I,i}}{1 - \sum_{I=0}^{PD} \vartheta_{I,i}} \quad (16)$$

$$\theta_{PMG,i} = \frac{1}{N} \sum_{i=1}^{N} \dot{\theta}_\iota \quad (17)$$

Additionally, the short run estimates are expressed as:

$$\Delta D_{i,t} = \vartheta_i \left[D_{i,t-I} - \theta_i X_{i,t} \right] - \sum_{I=0}^{PD-I} \vartheta_{I,i} \Delta_I W_{i,t-I} + \sum_{I=0}^{PX} \delta_{I,i} \Delta_I X_{i,t-I} + \sum_{I=0}^{PZ} \sigma_i I Z_t + \varepsilon_{i,t} \quad (18)$$

$$\breve{\alpha}_i = -(1 - \sum_{I=1}^{PD} \breve{\vartheta}_{I,i}) \quad (19)$$

$$\breve{\vartheta}_i = \frac{\sum_{I=0}^{PX} \breve{\delta}_{I,i}}{\breve{\alpha}_i} \quad (20)$$

$$\ddot{\theta}_{PMG} = \sum_{i=1}^{N} \breve{\theta}_i \quad (21)$$

3.3.5. Robustness check

To validate PMG and CS-ARDL results, we employ two additional techniques addressing cross-sectional dependence (CD): Common Correlated Effects Mean Group (CCEMG) and Augmented Mean Group (AMG). CCEMG ensures a common parameter across countries, asymptotically eliminating CD, while AMG, akin to CCEMG, captures unobserved common effects and utilizes first difference OLS. Consequently, the estimable model can be written as:

$$\begin{aligned} EDU_{it} = \alpha_i + c_i t + d_i \breve{\mu}_t^{va\Delta} + \beta_{i,1} GDP_{i,t} + \beta_{i,2} HDI_{i,t} + \beta_{i,3} UMP_{i,t} + \beta_{i,4} IEQ_{i,t} + \beta_{i,5} HEA_{i,t} + \beta_{i,6} EED_{i,t} \\ + \beta_{i,7} INQ_{i,t} + \beta_{i,8} ENER_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (22)$$

In the model, *i* denotes cross-sectional dimension (1, ..., *n*), *t* denotes period (1, ..., *t*), α_i signifies country-specific effects, and $d_{i,t}$ indicates heterogeneous deterministic trends. α_i correlates with independent variable coefficients varying across countries. Short-run dynamics and long-run adjustment occur through the error term ($\mu_{i,t} = \check{r}_i f_t + \varepsilon_{i,t}$). The vector f_t represents unobserved common shocks, whether stationary or nonstationary and does not affect estimation validity. AMG provides an explicit estimate for f_t, rendering μ_t^{va} economically meaningful while allowing serial correlation in $\varepsilon_{i,t}$.

4. Result and discussion

4.1. Result

Summary statistics indicate a mean educational level of 6.062 years (SD = 2.064), with skewed and high kurtosis distribution in **Table 2.** Real per capita GDP growth rate averages 1.349% (SD = 11.372), exhibiting positive skewness and high kurtosis. Human development index mean is 0.580 (SD = 0.172), showing a negatively skewed distribution. Unemployment rate averages 14.025% (SD = 5.996), with slight negative skewness. Income inequality mean Gini index is 0.588 (SD = 0.054), with negatively skewed distribution. Health expenditure averages 36.083 (SD = 23.101), government expenditure on education 9.527 (SD = 7.814), institutional quality −0.950 (SD = 0.368), and total energy consumption 0.944 (SD = 1.108), each with specific skewness and kurtosis characteristics.

Table 2. Descriptive statistics.

Variable	EDU	GDP	HDI	UMP	IEQ	HEA	EED	INQ	ENER
Mean	6.062	1.349	0.580	14.025	0.588	36.083	9.527	−0.950	0.944
Minimum	0.000	−47.900	0.000	3.507	0.488	0.000	0.000	−1.909	0.003
Maximum	9.573	96.956	0.748	29.770	0.686	76.694	26.124	0.000	4.093
Std. Dev.	2.064	11.372	0.172	5.996	0.054	23.101	7.814	0.368	1.108
Variance	4.259	129.331	0.030	35.948	0.003	533.667	61.056	0.135	1.228
Skewness	−1.243	3.420	−2.181	−0.190	−0.055	0.017	0.224	0.323	1.320
Kurtosis	5.216	33.653	8.008	1.994	2.129	1.885	2.057	4.111	3.740
Observation	184	184	184	184	184	184	184	184	184

Sources: Authors' computations (2024).

The correlation matrix highlights significant relationships between variables in **Table 3**. Education level (EDU) shows strong positive correlations with human development index (HDI) and moderate positives with health expenditure (HEA) and energy consumption (ENER). Conversely, EDU has a moderate negative correlation with income inequality (IEQ) and government expenditure on education (EED). Weak positive correlations are observed between unemployment (UMP) and institutional quality (INQ) with education levels.

Table 3. Correlation matrix.

Variable	EDU	GDP	HDI	UMP	IEQ	HEA	EED	INQ	ENER
EDU	1.000								
GDP	−0.062	1.000							
HDI	0.916	−0.054	1.000						

Table 3. (*Continued*).

Variable	EDU	GDP	HDI	UMP	IEQ	HEA	EED	INQ	ENER
UMP	0.166	−0.095	0.249	1.000					
IEQ	−0.377	−0.042	−0.292	0.201	1.000				
HEA	0.282	−0.119	0.418	0.382	−0.180	1.000			
EED	−0.072	−0.052	−0.213	−0.427	−0.161	−0.299	1.000		
INQ	0.143	0.061	0.104	0.038	−0.034	0.368	−0.166	1.000	
ENER	0.307	0.006	0.188	−0.380	−0.513	−0.005	0.069	0.204	1.00

Sources: Authors' computations (2024).

The study on macroeconomic determinants of education levels in AOECs employed slope homogeneity tests, utilizing Pesaran and Yamagata and Blomquist and Westerlund methodologies in **Table 4**. Significant deltas were found for both techniques, indicating varying slopes across independent variables. Adjusted deltas, like the 10.51*** and 9.366*** respectively for Pesaran and Yamagata and Blomquist and Westerlund, emphasize substantial heterogeneity, revealing comprehensive interactions between macroeconomic determinants and education levels.

Table 4. Slope homogeneity test.

MODEL: EDU = F (GDP, HDI, UMP, IEQ, HEA, EED, INQ, ENER)				
	PESARAN and YAMAGATA		BLOMQUIST and WESTERLUND	
	Delta	P-value	Delta	P-value
	7.901***	(0.000)	7.042***	(0.000)
Adj.	10.51***	(0.000)	9.366***	(0.000)

Note: * = 10%, ** = 5%, and *** = 1% significant level respectively. P-values in bracket. H0: slope coefficients are homogenous.
Sources: Authors' computations (2024).

The Pesaran (2015) cross-section dependence (CD) test indicates substantial cross-sectional dependence for all variables in **Table 5**, with CD test statistics ranging from 3.615 to 22.075, all yielding highly significant *p*-values ($p < 0.001$). Additionally, the weak cross-sectional dependence test confirmed this, revealing significant cross-sectional dependence across all variables, as evidenced by the highly significant CD statistics (ranging from 3.620 to 22.080) and associated *p*-values ($p < 0.001$). The tests' outcomes suggest that the assumption of weak cross-sectional dependence is rejected, indicating the presence of strong cross-sectional dependence among the variables.

Distinct patterns emerge among variables in the analysis, with key indicators exhibiting stable behavior at original levels (I (0)) according to the CIPS criterion. Cross-sectional ADF tests confirm stationarity at initial levels for several variables. Education levels, human development, unemployment, health expenditure, and institutional quality stabilize after first differencing (I (1)). The chosen analytical approach (PMG and CS-ARDL) is validated, ensuring robustness and providing a solid foundation for further analysis. Results are detailed in **Table 6**.

Table 5. Cross-section dependence test.

Pesaran (2015) CD test for variables:									
Variable:	**EDU**	**GDP**	**HDI**	**UMP**	**IEQ**	**HEA**	**EED**	**INQ**	**ENER**
CD test:	21.993	4.181	22.075	3.702	3.615	14.238	6.173	16.312	13.465
P-value:	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Weak cross-sectional dependence test:				
Variable	**CD**	**CDw**	**CDw+**	**CD***
EDU	21.990*** (0.000)	11.120*** (0.000)	127.500*** (0.000)	−3.870*** (0.000)
GDP	4.180*** (0.000)	1.740* (−0.082)	32.790*** (0.000)	2.920** (−0.003)
HDI	22.080*** (0.000)	10.320*** (0.000)	127.130*** (0.000)	2.210** (−0.027)
UMP	3.700*** (0.000)	0.410 (−0.681)	45.230*** (0.000)	1.780* (−0.075)
IEQ	3.620*** (0.000)	2.070** (−0.039)	73.230*** (0.000)	−0.130 (−0.894)
HEA	14.240*** (0.000)	8.310*** (0.000)	86.330*** (0.000)	0.350 (−0.729)
EED	6.170*** (0.000)	3.150** (−0.002)	61.890*** (0.000)	−1.600 (−0.109)
INQ	16.310*** (0.000)	6.260*** (0.000)	91.860*** (0.000)	0.380 (−0.704)
ENER	13.470*** (0.000)	7.950*** (0.000)	91.190*** (0.000)	1.550 (−0.121)

Note: * = 10%, ** = 5%, and *** = 1% significant level respectively. *P*-values in bracket.CD: Pesaran (2015, 2021), CDw: Juodis, Reese (2021), CDw+: CDw with power enhancement from Fan et al. (2015), and CD*: Pesaran, Xie (2021) with 4 PC(s).H0: weak cross-section dependence. H1: strong cross-section dependence.
Sources: Authors' computations (2024).

Table 6. Panel unit root tests.

Second generation unit root tests:										
Variable	**Cross section ips (cips):**					**Cross section adf (cadf):**				
	Constant		**Trend**		**Order**	**Constant**		**Trend**		**Order**
	Level	**Diff.**	**Level**	**Diff.**		**Level**	**Diff.**	**Level**	**Diff.**	
EDU	−1.685	−2.281*	−0.784	−2.341*	I (1)	−2.115	−2.865*	−1.062	−3.044*	I (1)
GDP	−3.557*	−5.603*	−3.728*	−5.646*	I (0)	−3.173*	−4.643*	−3.035*	−4.544*	I (0)
HDI	−1.780	−2.766*	−0.680	−2.278*	I (1)	−1.848	−2.959*	−0.434	−2.197	I (1)
UMP	−1.565	−2.342*	−1.147	−2.577*	I (1)	−2.337*	−2.392*	−2.156	−2.604	I (0)
IEQ	−2.619*	−2.051*	−1.074	−2.196*	I (0)	−2.532*	−2.060	−2.141	−2.289	I (0)
HEA	−1.574	−4.854*	−2.445	−4.852*	I (1)	−1.300	−3.510*	−2.827*	−3.464*	I (1)
EED	−3.525*	−5.277*	−3.763*	−5.180*	I (0)	−3.104*	−5.250*	−3.625*	−5.145*	I (0)
INQ	−2.035	−4.707*	−2.460	−4.638*	I (1)	−2.953*	−3.925*	−3.387*	−3.719*	I (0)
ENER	−2.886*	−4.804*	−2.922*	−4.941*	I (0)	−2.317*	−3.703*	−2.453	−4.130*	I (0)

Note: * = 10% significant level.
Source: Authors' computations (2024).

In **Table 7**, static results using POLS, FE, RE, and FD reveal varying relationships between macroeconomic determinants and education levels across different techniques. Starting with GDP, findings across the models show mixed results. While the POLS model indicates a negative and statistically insignificant relationship between GDP and education levels, both the FE and RE models exhibit positive but insignificant associations. This contradictory finding challenges the theoretical expectation of a positive link between economic growth and education levels. On the other hand, the human development (HDI) consistently demonstrates a strong positive relationship with education levels across all estimation techniques. This aligns with theoretical expectations and past empirical evidence, suggesting that sustainable human development promotes access to education. Furthermore, the unemployment rate (UMP) also presents mixed results. While POLS, FE, and RE models show a positive and significant association between unemployment and education levels, the FD model indicates a weaker, albeit positive, relationship. This implies that changes in unemployment rates may not substantially impact education levels in a static economy. Conversely, income inequality (IEQ) consistently exhibits a negative relationship with education levels, except for the FD model, where it shows a positive but marginally significant association. This negative relationship is in line with economic theory, emphasizing the adverse effects of income inequality on access to education. Similarly, health outcomes (HEA) show a consistent negative relationship with education levels across all models, suggesting that higher government health expenditure is associated with lower education levels. This finding contradicts economic theory and necessitates further investigation into the underlying mechanisms. The negative relationship between health outcomes and education levels, while unexpected, can be attributed to the trade-off between government spending on health and education, where increased allocation to health may come at the expense of education funding. Moreover, government expenditure on education (EED) consistently exhibits a positive and highly significant relationship with education levels, supporting the importance of government investment in education for human capital development. However, institutional quality (INQ) presents mixed results, with POLS and RE models showing a positive and significant relationship, while the FE model indicates a negative association. This calls for a further exploration of the role of institutions in shaping educational outcomes in AOECs. Finally, energy consumption (ENER) shows a positive relationship with education levels across all models, emphasizing the importance of energy availability in facilitating educational development.

Table 7. Static analyses.

Model: EDU = F (GDP, HDI, UMP, IEQ, HEA, EED, INQ, ENER)				
VARIABLE	**POLS**	**FE**	**RE**	**FD**
GDP	−0.005 (0.107)	0.001 (0.890)	−0.005 (0.299)	−0.006 (0.237)
HDI	11.174*** (0.000)	11.158*** (0.000)	11.174*** (0.000)	9.032*** (0.000)
UMP	0.031** (0.001)	0.055*** (0.000)	0.031** (0.005)	0.103 (0.294)

Table 7. (*Continued*).

Model: EDU = F (GDP, HDI, UMP, IEQ, HEA, EED, INQ, ENER)				
VARIABLE	**POLS**	**FE**	**RE**	**FD**
IEQ	−3.217** (0.007)	−8.962** (0.001)	−3.217** (0.008)	37.970* (0.098)
HEA	−0.015*** (0.000)	−0.009*** (0.000)	−0.015*** (0.000)	−0.017** (0.031)
EED	0.029*** (0.000)	−0.001 (0.791)	0.029*** (0.000)	0.001 (0.940)
INQ	0.566** (0.002)	−0.321** (0.023)	0.566*** (0.000)	0.099 (0.691)
ENER	0.175** (0.014)	0.594*** (0.000)	0.175** (0.004)	−1.236 (0.195)
CONS.	1.661* (0.054)	3.560** (0.032)	1.661* (0.062)	6.370*** (0.000)
CDT	0.07 (0.947)	0.34 (0.736)		13.90*** (0.000)
R2	0.891	0.936		0.645
N	184	184	184	176

Note: * = 10%, ** = 5%, and *** = 1% significant level respectively. *P*-values in bracket. CDT = cross section dependent test for residuals.
Sources: Authors' computations (2024).

The dynamic analysis in **Table 8**, utilizing PMG and CS-ARDL models, elucidates the long run and short run connections between macroeconomic determinants and education levels in AOECs. In the PMG model, GDP demonstrates a statistically significant negative relationship with education levels in the long run, contrary to conventional wisdom. Conversely, HDI exhibits a significant positive association with education levels in both long and short terms, emphasizing the imperative of human development for educational enhancement. Unemployment and income inequality display inconsistent relationships across models, with no significant impacts discerned. Health expenditure reveals a positive long-term relationship with education levels but contradicts expectations with a negative short-term effect, warranting further investigation. Moreover, government expenditure on education fails to exhibit significant connections with education levels in both PMG and CS-ARDL models, indicating potential inefficiencies in resource allocation. Similarly, institutional quality yields mixed results, suggesting the complexity of governance's role in educational outcomes. Notably, energy consumption demonstrates a robust positive association with education levels in the long run in the PMG model, indicating the potential benefits of economic activity linked to higher energy consumption. However, the CS-ARDL model unveils a weak negative impact of energy consumption on education levels in the long run and no significant relationship in the short term, highlighting discrepancies between short- and long-term effects. Finally, the error correction term (ECM) underpins the model's validity, indicating a robust long-run equilibrium between independent variables and education levels.

Table 8. Dynamic analyses.

MODEL: EDU = *F* (GDP, HDI, UMP, IEQ, HEA, EED, INQ, ENER)							
PMG				**CS-ARDL**			
Long run		**Short run**		**Long run**		**Short run**	
GDP	−0.199** (0.003)	ΔGDP	0.001 (0.938)	GDP	0.006 (0.599)	ΔGDP	0.020 (0.491)
HDI	13.834*** (0.000)	ΔHDI	10.497*** (0.000)	HDI	5.954*** (0.000)	ΔHDI	10.044*** (0.000)
UMP	−0.057 (0.191)	ΔUMP	0.084 (0.250)	UMP	0.061 (0.125)	ΔUMP	0.094 (0.129)
IEQ	21.640 (0.144)	ΔIEQ	−8.143 (0.158)	IEQ	−10.768 (0.209)	ΔIEQ	−25.160 (0.257)
HEA	0.054* (0.074)	ΔHEA	−0.003* (0.087)	HEA	0.015 (0.348)	ΔHEA	0.040 (0.336)
EED	0.003 (0.886)	ΔEED	−0.001 (0.252)	EED	−0.002 (0.762)	ΔEED	0.001 (0.948)
INQ	−1.020 (0.168)	ΔINQ	0.006 (0.820)	INQ	−0.151 (0.360)	ΔINQ	−0.382 (0.285)
ENER	1.401*** (0.000)	ΔENER	0.763 (0.311)	ENER	−0.725* (0.084)	ΔENER	−1.089 (0.193)
CONS.	−0.813* (0.073)	ECM (−1)	−0.046** (0.047)			EDU (−1)	−0.723*** (0.000)
						ECM (−1)	−1.723*** (0.000)
N	176		176		176		176

Note: * = 10%, ** = 5%, and *** = 1% significant level respectively.
Sources: Authors' computations (2024).

The robustness check in **Table 9** using AMG and CCEMG models reaffirms the relationship between macroeconomic determinants and education levels in AOECs. Both models find statistically insignificant negative coefficients for GDP growth, suggesting no significant link between GDP growth and education levels in AOECs. Conversely, HDI exhibits significant positive coefficients in both models, highlighting the advantageous impact of human development on education levels. The unemployment rate displays mixed results, with a significant positive coefficient in the AMG model but an insignificant relationship in the CCEMG model, emphasizing the need for further investigation. Income inequality shows insignificant negative coefficients in both models, aligning with theoretical expectations. Health expenditure yields negative and insignificant coefficients, contrasting with dynamic models, indicating a nuanced relationship. Government expenditure on education remains statistically insignificant, consistent with previous findings, highlighting resource allocation concerns. Institutional quality exhibits mixed and insignificant coefficients across models, suggesting no robust relationship with education levels. Energy consumption demonstrates an insignificant negative coefficient in the AMG model but a significant negative coefficient in the CCEMG model, indicating potential adverse effects on education levels, necessitating further exploration. Overall, the PMG and CS−ARDL models revealed significant long−term associations, such as the negative impact of GDP and the positive influence of human development on education levels. However, when we applied the AMG and CCEMG models, which account for cross−sectional dependence differently, the results showed some variations. For instance, the AMG and CCEMG models confirmed the negative relationship between GDP growth and education. These discrepancies can be attributed to the differences in how each model handles cross—sectional dependence and the heterogeneity of the data.

Table 9. Robustness check.

Model: EDU = *F* (GDP, HDI, UMP, IEQ, HEA, EED, INQ, ENER)		
Variable	**AMG**	**CCEMG**
GDP	−0.004 (0.608)	−0.004 (0.586)
HDI	10.955*** (0.000)	10.963*** (0.000)
UMP	0.196* (0.064)	0.072 (0.446)
IEQ	−15.052 (0.131)	−2.931 (0.681)
HEA	−0.002 (0.120)	−0.009 (0.127)
EED	−0.001 (0.644)	0.001 (0.781)
INQ	−0.103 (0.261)	0.266 (0.458)
ENER	−1.043 (0.129)	−0.536** (0.032)
CONS.	6.829 (0.283)	4.240 (0.515)
N	184	184

Note: * = 10%, ** = 5%, and *** = 1% significant level respectively.
Sources: Authors’ computations (2024).

4.2. Discussion

The mixed results for GDP indicate that economic growth does not uniformly impact education levels in these countries. While economic theory suggests that rising GDP should enhance access to education through better resources, the insignificant findings may point to inefficiencies in translating economic growth into educational improvements. This could be due to structural issues or the uneven distribution of economic gains across populations or how the sources of growth in AOECs may not be driven by improvement in education attainments. Additionally, the strong positive relationship between human development index and education levels aligns with past studies showing that strategic human development positively influences education levels. This highlights the importance of human development efforts in promoting educational advancement, particularly in developing economies. Similarly, the positive relationship between unemployment and education suggests that individuals may turn to education as a way to improve their job prospects during periods of economic uncertainty. However, the weaker short−term effect indicates that this is a long−term strategy rather than an immediate response to rising unemployment. The consistent negative relationship between income inequality and education levels supports the theory that greater inequality hinders access to education. This may reflect how wealthier groups can afford better educational opportunities, leaving disadvantaged populations with fewer resources and limited access to quality education. Conversely, the unexpected negative relationship between health expenditure and education suggests that when governments allocate more resources to healthcare, it may reduce the funds available for education. In resource−scarce countries, this trade−off could explain the negative association and further research is needed to understand the dynamics between health and education levels. In addition, the significant positive impact of government education spending underscores the importance of public investment in education. However, the insignificant results in dynamic models may suggest inefficiencies in how resources are allocated, indicating a need for policy reform to ensure that increased spending directly improves educational outcomes. The mixed results for institutional quality reflect the complexity of governance in AOECs. While stronger institutions generally support better education systems, institutional inefficiencies, corruption, and political instability could undermine these efforts, leading to inconsistent outcomes. Finally, the positive relationship between energy consumption and education is in line with previous findings that emphasize the role of infrastructure and energy availability in facilitating educational access. Reliable energy sources are crucial for modern educational facilities, particularly in developing regions where electricity shortages can disrupt learning.

5. Conclusion and policy recommendations

This study investigates the macroeconomic determinants influencing education levels in AOECs, focusing on eight nations (Algeria, Angola, Congo, Equatorial Guinea, Gabon, Egypt, Libya, and Nigeria) over the period 2000–2022. Drawing on human capital theory, the research examines factors such as income inequality, health outcome, economic growth, human development, unemployment, education expenditure, institutional quality, and energy consumption. Utilizing a robust panel data framework, the study employs various estimation strategies and tests to analyze the relationships among these determinants and education levels. Methodologically, the study employs rigorous statistical techniques such as slope homogeneity tests, cross−sectional dependence tests, and second−generation unit root tests for preliminary investigation. The results highlight substantial heterogeneity in slopes across independent variables and significant cross−sectional dependence among variables. Analyzing stationarity using second−generation unit root tests, the study finds stable behavior for key indicators at their original levels, with some variables requiring first differencing for stability. Furthermore, empirical static analyses using POLS, FE, RE, and FD models reveal nuanced relationships between macroeconomic factors and education levels. Likewise, dynamic analyses using augmented autoregressive distributed lag families (PMG and CS−ARDL) confirms the dynamic relationships between macroeconomic determinants and education levels.

In conclusion, the static analysis reveals nuanced insights into the impact of key parameters on education levels. For instance, while GDP exhibits varying relationships across models, the positive and significant association between HDI, unemployment, and education levels aligns with theoretical expectations and corroborates prior empirical evidence. Income inequality consistently demonstrates a negative relationship with education levels, emphasizing the adverse effects of economic disparity on educational access. The unexpected negative relationship between health outcomes and education levels prompts further investigation into the underlying mechanisms. Government expenditure on education reveals a positive nexus with education levels, underscoring the crucial role of public investment in human capital development. Institutional quality presents mixed results, indicating the need for a nuanced exploration of its role in shaping educational outcomes. Energy consumption consistently shows a positive relationship with education levels, highlighting the importance of energy availability in facilitating educational development. Additionally, the dynamic analysis deepens understanding of the long–run and short–run relationships. For instance, while GDP's negative impact on education levels, in the long run, contradicts conventional expectations, HDI emerges as a robust determinant of higher education levels in both short and long–run analyses. The mixed findings regarding the impact of unemployment, income inequality, health outcome, government spending on education, institutional quality, and energy consumption underscore the complexity of dynamic relationships over time. Robustness checks using AMG and CCEMG models validate and extend the dynamic analysis, reaffirming the significance of human development in enhancing education outcomes. Collectively, the study's robust methodology, diverse regression models, and thorough analysis enhance the reliability and validity of the findings, paving the way for future research and policy formulation which are:

1) Targeted Human Development Programs: The study's strong positive connection between HDI and education levels suggests that improvement in human development programs and awareness can enhance educational levels. Policymakers should implement targeted infrastructure investments in underserved areas to help economically disadvantaged communities access education and improvement in the quality of life.
2) Enhanced Public Investment in Education: The positive link between government spending and education outcomes emphasizes the need for increased public investment in education infrastructure, teacher training, and resources. Policymakers should strategically reallocate budgets to prioritize education, potentially leveraging international partnerships to address funding gaps.
3) Institutional Reforms for Good Governance: Mixed findings on institutional quality highlight the importance of governance reforms. Policymakers should strengthen regulatory frameworks, enhance transparency, and reduce corruption to improve education outcomes. Incremental reforms, starting with critical areas like corruption control, are key to making progress in AOECs.
4) Sustainable Energy Infrastructure Development: The positive association between energy consumption and education levels points to the need for reliable energy access in schools. Policymakers should invest in renewable energy and improve energy efficiency in educational institutions, utilizing public–private partnerships and international funding to support these initiatives.

For the practical applicability of these recommendations, it is paramount to recognize the economic as well as political limitations regarding AOECs. For instance, even though increasing public investment in education is vital; it must not neglect other pressing needs like healthcare and infrastructure. In a phased manner, policymakers can opt for increasing educational spending gradually depending on available fiscal space with an emphasis on the most priority investments first. Besides that, institutional reforms should be drawn from the local political context so that they are workable and persistent over time.

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