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Economic Growth and Energy Consumption in the CEMAC Zone

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Abstract

Despite existing studies on the environmental effect of economic growth, no study has yet established the relationship between economic growth and energy consumption in the Congo Basin countries. Thus, this study aims to analyze the relationship between economic growth and energy consumption. Specifically, it is a question of evaluating the effect of economic growth on energy consumption on the one hand and analyzing the causality between the two variables on the other. To achieve the first objective, we mobilized FMOLS and DOLS estimation techniques. For the second objective, we used the Granger causality test. The results suggest that economic growth significantly increases energy consumption. Furthermore, the Granger causality test allows us to validate the retroactivity hypothesis for the CEMAC zone economies. Consequently, the CEMAC zone must put in place an energy efficiency policy based on the use of new technologies such as biomass, hydrogen, wind and solar power in order to allow the different governments to progressively engage in the path of low-carbon growth and ensure the transition to a greener economy.

Keywords

Economic Growth, Energy Consumption, Causality Test, Retroactivity Hypothesis

1. Introduction

Economic growth is defined as a sustained increase over one or more long periods (one year) in the Gross Domestic Product (GDP) in real terms. There are two forms of growth: extensive growth, which is proportional to the increase in the quantities of factors of production, and intensive growth, which is linked to the increase in the productivity of labor and capital. Thus, the economic growth of a country is inexorably linked to its productive capacity.

Several developing countries have elaborated their development plan in order to achieve economic emergence during the last decade. To this end, the countries of the Economic and Monetary Community of Central Africa are not left behind in this dynamic. Among the six countries of the sub-region, five have already set their economic emergence deadlines. These are Congo and Gabon, which have declared their emergence ambitions in 2025, Equatorial Guinea in 2020, Chad in 2030 and Cameroon in 2035. The only country absent from this meeting is the Central African Republic, which is going through an unprecedented security crisis. However, it is important to note that if the CEMAC countries intend to follow the path of economic emergence, they will have to achieve a sustainable level of growth.

Long-term analysis of the economic performance of CEMAC countries shows that average growth over the past two decades has been weak, as shown in **Figure 1**. In addition, CEMAC economies have structural weaknesses that hinder their economic takeoff: they are based on a limited number of raw materials, integration is not very advanced, and the zone's competitiveness is weak. At the same time, CEMAC faces critical challenges, including managing a deep economic crisis, preserving peace and security, and protecting its valuable ecosystem (WTO, 2013).

This ambition to emerge requires a break in the CEMAC's growth dynamic. Based on World Bank data, we calculated the average growth of CEMAC countries during the period 2000-2018. It follows from this calculation that economic growth has averaged 4.8% per year. Economic emergence requires a doubling of this dynamic over the next decade. To achieve this, CEMAC must undertake a deep transformation from a non-diversified economy with low value added to a diversified economy with high value added. Relying today on a fragile footing (raw materials), it will rely tomorrow on three main levers: the Energy pillar, the Agriculture and Forest Economy pillar and the Mining and Metallurgy pillar.

Sustainable economic growth in Africa will inexorably result in increasing energy demand and carbon dioxide (CO_2) emissions. Africa is recognized as the continent that contributes the least to greenhouse gases (GHGs), however, it is among the regions hardest hit by climate change. Therefore, while meeting immediate energy needs is a priority, there is also a need to address environmental and climate challenges to enable the continent to gradually move towards low-carbon growth and transition to a greener economy (Groupe de la BAD, 2013).

Regardless of the trajectory Africa takes, the continent's influence on global energy trends is growing. The growing urban population is translating into rapid growth in energy demand for industrial production, cooling needs and mobility. Energy demand in Africa is growing at twice the global average. Africa's vast renewable resources coupled with lower technology costs are driving double-digit growth in solar photovoltaic (PV) and other renewable energy deployments across the continent. With its growing appetite for modern, efficient energy

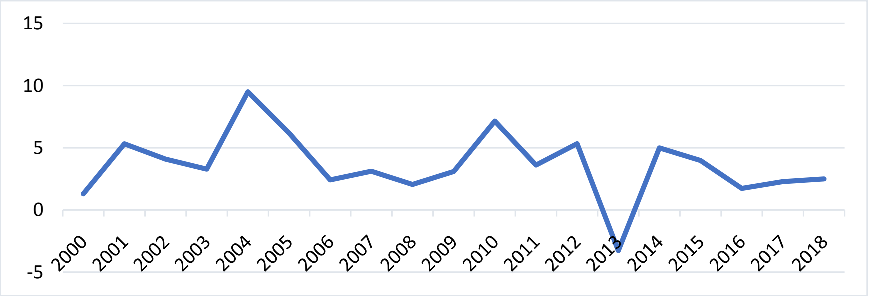

Figure 1. Evolution of the average annual growth rate from 2000 to 2018 in the CEMAC zone. Source: Authors based on WDI data.

sources, Africa is emerging as a key player in global oil and gas markets. With a doubling of the vehicle fleet (most of which is made up of fuel-efficient vehicles) and increased use of liquefied petroleum gas (LPG) for clean cooking, Africa's demand for oil will increase by 3.1 million barrels per day by 2040, more than China's projected increase and just behind India's. Africa's growing weight is also felt in natural gas markets: over the same period, the continent becomes the third largest source of global gas demand growth (IEA, 2019).

Africa will pass the 2 billion mark by 2050, representing 25% of the world's population, compared to 17% today (The Guardian, 2022). As a result, this demographic boom will create both opportunities and enormous challenges. While the size of the African economy is four times larger in 2040 than it is today, progress in energy efficiency is helping to limit the increase in total primary energy demand to only 50% (IEA, 2019). Africa has the world's leading solar resources, but has only installed 5 gigawatts (GW) of solar PV, less than 1% of global installed capacity (IEA, 2019). In general, CEMAC countries have a low level of renewable energy consumption over the past two decades as shown in **Figure 2**.

Using data from the World Bank, we have represented the evolution of the consumption of renewable energies for the economies of the CEMAC countries.

Fossil fuels, oil, natural gas and coal, currently provide about 80% of the energy used in the world. This means that the prospect of their depletion poses a major problem for human societies. However, all experts agree that these resources are solar energy accumulated by nature in the form of biomass that has become carbon and carbon compounds over millions of years of geological ages and that they are not renewable on a human time scale (AFD & BAD, 2009).

This overconsumption of fossil fuels in the world is alarming and has been the specific subject of goal 12 of sustainable development: responsible consumption and production. This goal aims to do more and better with less. It also aims to decouple economic growth and environmental degradation by increasing resource efficiency and promoting sustainable lifestyles. In addition, sustainable consumption and production can also contribute to poverty reduction and the transition to green, low-carbon economies.

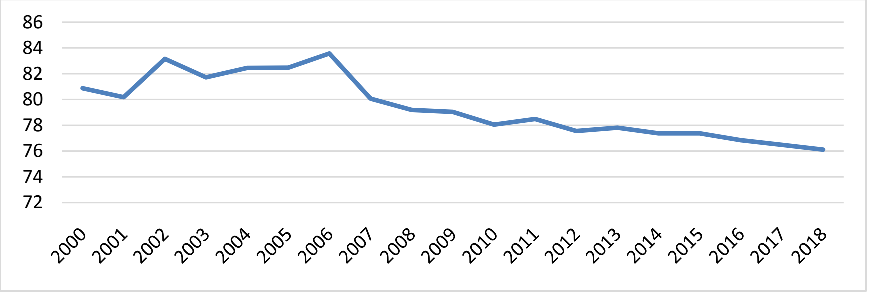

Figure 2. Evolution of the average consumption rate of renewable energy from 2000 to 2018 in the CEMAC zone. Source: Authors based on WDI data.

In recent decades, the relationship between energy consumption and economic growth has become a recurrent issue in the debate on economic and social development policies and also environmental protection. At present, many researchers in this field are questioning the direction of causality between energy consumption and economic growth. Thus, knowledge of the causal relationship between economic variables can provide important elements for the implementation of adequate economic policies (Bourbonnais, 2003).

The relationship between economic growth and energy consumption has been little studied in underdeveloped countries, even though there is unanimous agreement on the need to know this relationship in order to implement effective energy policies. This need has been amplified recently with the repeated energy crises in several regions and the continuous rise in energy prices in general and oil prices in particular.

Energy is essential to the realization of any production process and therefore to economic and social development. The role that energy plays or has played in economic growth is no longer in question. On the other hand, understanding the relationship between these two variables remains a question open to several interpretations and approaches.

After 1960, several economists (Berrah, 1983; Matly, 1983; Meallier & Chouard, 1986; Hourcade & Ben Chaabane, 1991) focused on the evaluation and determinants of energy demand and the modeling of energy demand in relation to economic activity, based on unit elasticity, which led to the idea that energy consumption and gross domestic product grew at the same rate. This law has given rise to much controversy and has finally given way to the thesis that it is possible to disconnect the movement of these two variables and achieve an elasticity that is less than unity.

For Spierer (1982), energy use therefore contributes to the improvement of living conditions and the quality of work. It is, in the same way as information technology, a vital asset for society today. According to this author, the socio-economic environment in general, and the national economy in particular, have a definite influence on the energy sector. They determine by their evolution, the needs in final energy and thus of the production of this sector.

For Mirabel et al. (2000), the relationship between energy consumption and

GDP depends on the productive structure, the technology used, the climate, the regulations in force and the price of energy, all of which influence the energy content of a country's domestic wealth. According to Squalli (2007), an increase (respectively a decrease) in energy consumption leads to an increase (respectively a decrease) in real GDP. In this case, energy causes GDP and the economy is significantly dependent on energy. If there is a negative impact, it may be due to excessive energy consumption in the unproductive sectors of the economy, a capacity constraint or an inefficient energy supply.

Given that the countries of the CEMAC zone have clearly developed their economic emergence plans, they will certainly carry out major reforms and changes that will enable them to follow the path of sustained and sustainable economic growth. This economic growth is not without consequences on energy consumption. Hence, the objective of this study is to analyze the relationship between economic growth and energy consumption in the CEMAC zone. This work is important on at least three levels. First, CEMAC is part of the Congo Basin, which is the world's second most important lung for the planet and humanity after the Amazon. It is endowed with an enormous potential in natural resources. Secondly, in a context of global warming due to increasing anthropogenic activities, it is important to assess the effect of economic growth on energy consumption in order to propose green growth strategies to decision makers. Finally, this study is the first to analyze the relationship between economic growth and energy consumption in a few countries of the Congo Basin in a context of under-consumption of renewable energy.

This work has a total of five sections. In addition to the general introduction presented in section one, section two highlights the literature review. The methodology of the study is devoted to section three. Section four presents the results and section five concludes.

2. Theoretical Foundations and Empirical Evidence of the Relationship between Economic Growth and Energy Consumption

This section, will present the causality between economic growth and energy consumption through the theoretical linking and empirical evidences.

2.1. Theoretical Foundations of the Causal Relationship between Energy and Economic Growth

The economic literature divides the relationship between energy and growth into four assumptions: growth, conservation, feedback and neutrality.

First, the growth hypothesis postulates that energy consumption can directly affect economic growth and indirectly complement labor and capital in the production process. Empirical support for the growth hypothesis is based on the presence of unidirectional causality from energy consumption to economic growth. In this case, policies to reduce energy consumption will have negative effects on economic growth.

Unlike the growth hypothesis, the conservation hypothesis does not postulate a unidirectional causality from economic growth to energy consumption. The conservation hypothesis states that energy conservation policies aimed at reducing energy consumption will have no negative impact on real GDP. The conservation hypothesis is supported when there is unidirectional causality from economic growth to energy consumption.

In contrast to the conservation hypothesis, the feedback hypothesis (or retroactivity hypothesis) assumes bidirectional causality between economic growth and energy consumption. Third, the feedback hypothesis asserts that energy consumption and economic growth are closely related and may well serve as complements to each other. The feedback hypothesis states that there is a bidirectional causal link between energy consumption and economic growth. Unlike the retroactivity hypothesis, the neutrality hypothesis postulates the absence of causality between the two variables.

The neutrality hypothesis considers energy consumption to be a relatively unimportant component of overall production and thus will have little or no impact on economic growth. As with the conservation hypothesis, energy conservation policies would not harm economic growth. The absence of a causal link between energy consumption and economic growth lends support to the neutrality hypothesis.

These hypotheses are contrasted and highlight the absence of unanimity between energy consumption and economic growth. This is why other contributions on this subject are still of interest to the understanding of the link between energy consumption and economic growth

2.2. Empirical Evidence of the Causal Relationship between Economic Growth and Energy

Several works have analyzed the causality between energy consumption and economic growth. Like the theoretical work, this work is ambiguous and inconclusive.

Zachariadis (2007) applied bivariate causality tests between energy and growth for Canada, France, Germany, Italy, Japan, the United Kingdom and the United States, using aggregate, sectoral data and three different modern econometric methods: VEC model, ARDL model and the Toda-Yamamoto approach. The results, which are often contradictory or economically implausible, explicitly illustrate that one should be cautious in developing policy implications using bivariate causality tests on small samples.

Apergis & Payne (2009) examined the relationship between energy consumption and economic growth in six Central American countries over the period 1980-2004 in a multivariate framework. Given the relatively short period of time series data, a panel cointegration and the error correction model were employed to infer the causal relationship based on the heterogeneous panel cointegration test by Pedroni. The causality results indicate the presence of two short-run and long-run causalities from energy consumption to economic growth that supports the growth hypothesis.

Kalyoncu et al. (2010) use data on energy consumption and economic growth for 51 countries over the period from 1971 to 2005. They divide the countries into three groups: low income group, lower middle income group and upper middle income group countries. For this purpose, they test the cointegration relationship using the method of Pedroni (1999). The authors used panel causality tests to investigate the type of causality and continue the analysis by investigating the strength of the relationship between these variables using the Pedroni (2001) method. The empirical results of this study show that: energy consumption and GDP are cointegrated for all three groups, the results of the panel causality tests reveal that there is a long-run Granger causality from GDP to energy consumption for low-income countries and there is bidirectional causality between energy consumption and GDP for middle-income countries. The study showed, however, that there is no strong relationship between energy consumption and economic growth for all income groups considered in this study.

Yazdani & Faaltofighi (2013) studied the causal relationship between economic growth and energy consumption during the period 1980 - 2007. Seven countries were selected as samples and were divided into two groups: oil exporters (Iran and Saudi Arabia) and importers (Iran, Saudi Arabia, Turkey, South Korea, Malaysia, India and Pakistan). The results show that in the oil exporting countries, the growth hypothesis is accepted and the causal relationships are from energy consumption to GDP. In contrast, the conservation hypothesis is accepted in oil-importing countries. In other words, an increase in GDP leads to an increase in energy consumption and, therefore, savings policies could be used in these countries without destructive impacts on their economic growth.

Coers & Sanders (2013) used a panel of 30 OECD countries over the last 40 years using unit roots and panel cointegration tests and specify an appropriate error correction model to analyze the link between income and energy consumption. Their results show the existence of bidirectional causality in the very short run, on the one hand, and strong unidirectional causality from GDP to energy consumption in the long run, on the other.

Ghouali et al. (2014) have examined the relationship between energy consumption and economic growth for a sample of 13 countries classified into two groups according to region: "Maghreb Countries (Algeria, Morocco, Tunisia, Libya, Egypt) and Middle East Countries (Iran, Bahrain, Saudi Arabia, United Arab Emirates, Qatar, Oman, Lebanon and Jordan)", while using cointegration panel tests during the period 1980-2010. They demonstrate a cointegrating relationship between electricity consumption and economic growth, thus the existence of a long-run equilibrium relationship.

Guellil (2016) studied the relationship between global energy consumption and different aspects such as economic, environmental, political, and that for the six continents, using panel data cointegration tests and Panel Granger Causality tests. The results indicate bidirectional, unidirectional and neutral causality relationships between energy consumption and some variables, which could be a good tool to prioritize the allocation of resources between sectors to ensure better energy policy and economic performance.

Mivumbi & Yuan (2021) have analysed the relationship between Rwanda's environmental pollution and Economic Growth. By using the Johansen Co-integration test, verification of long runs co-integration equilibrium Rwanda's air pollution was found to depend on energy consumption significantly and economic growth insignificantly with positive coefficient and, slightly incline CO_2 emission pollution.

Contrary to previous studies, no work has yet focused on the specific case of the Congo Basin countries. Yet, the Congo Basin is the world's second lung, vital for the planet and humanity after the Amazon. Moreover, none of these studies have combined an analysis of the effect and causality between economic growth and energy consumption. These shortcomings of the literature form the basis of this study.

3. Methodological Approach

3.1. Data

The data used for this study are annual and extend from 1960 to 2014 and cover the six CEMAC countries (Cameroon, Central African Republic, Congo, Gabon, Equatorial Guinea and Chad). They are obtained from the World Bank database. The endogenous variable here is total primary energy consumption (ENR_{it}) (in Quadrillion Btu). As for the exogenous variables, we distinguish: 1) GDP_{it}: represents the GDP (Gross Domestic Product) for the country *i* in year *t* and it's defined in dollars at current prices. According to the conservation hypothesis, any increase in GDP is associated with an increase in energy. 2) $INTE_{it}$ represents the energy intensity measured by the ratio between energy consumption and GDP for country *i* in year *t*. According to Tsani (2010), energy is considered as a simple input in neoclassical growth models. 3) CO_{2it} represents the total carbon dioxide emissions (metric tons per capita) from energy consumption for country *i* in year *t*. The expected sign of the coefficient associated with this variable is positive. 4) POP_{it} represents the population (in millions) for country *i* in year *t*. The expected sign of this variable is positive or negative. 5) FDI_{it} represents Foreign Direct Investment (in constant US Dollars) for country *i* in year *t*. The expected sign of this variable is positive or negative.

3.2. Specification of the Econometric Model

The empirical model we use is taken from the work of Pedroni (1999, 2000, 2001). The model is presented as a linear relationship between the different variables expressed. This integrated model of total primary energy demand is expressed as follows:

$$\log \mathrm{ENR}_{it} = \lambda_0 + \lambda_1 \log \mathrm{GDP}_{it} + \lambda_2 \log \mathrm{FDI}_{it} + \lambda_3 \log \mathrm{CO2}_{it} + \lambda_4 \log \mathrm{POP}_{it} + \lambda_5 \log \mathrm{INTE}_{it} + U_i + V_t + \varepsilon_{it} \quad (1)$$

where ε_{it}, U_i and V_t designate respectively the error term, the unobserved specific effects of country i and the unobserved time effect for each country. The coefficients λ_i are parameters to be estimated. The basic model for the causality test is based on the work of Honoré (2018). The VAR model is structured as follows:

$$\mathrm{ENR}_{it} = \beta_0 + \sum_{i=1}^{k} \beta_1 \mathrm{ENR}_{it-1} + \sum_{i=1}^{k} \beta_2 \mathrm{CO2}_{it-1} + \sum_{i=1}^{k} \beta_3 \mathrm{FDI}_{it-1} + \sum_{i=1}^{k} \beta_4 \mathrm{POP}_{it-1} + \sum_{i=1}^{k} \beta_5 \mathrm{GDP}_{it-1} + \sum_{i=1}^{k} \beta_6 \mathrm{INTE}_{it-1} + \theta_t$$

$$\mathrm{INTE}_{it} = \beta_0 + \sum_{i=1}^{k} \beta_1 \mathrm{INTE}_{it-1} + \sum_{i=1}^{k} \beta_2 \mathrm{CO2}_{it-1} + \sum_{i=1}^{k} \beta_3 \mathrm{FDI}_{it-1} + \sum_{i=1}^{k} \beta_4 \mathrm{POP}_{it-1} + \sum_{i=1}^{k} \beta_5 \mathrm{ENR}_{it-1} + \sum_{i=1}^{k} \beta_6 \mathrm{GDP}_{it-1} + \varepsilon_t$$

$$\mathrm{CO2}_{it} = \beta_0 + \sum_{i=1}^{k} \beta_1 \mathrm{CO2}_{it-1} + \sum_{i=1}^{k} \beta_2 \mathrm{GDP}_{it-1} + \sum_{i=1}^{k} \beta_3 \mathrm{FDI}_{it-1} + \sum_{i=1}^{k} \beta_4 \mathrm{POP}_{it-1} + \sum_{i=1}^{k} \beta_5 \mathrm{ENR}_{it-1} + \sum_{i=1}^{k} \beta_6 \mathrm{INTE}_{it-1} + \gamma_t$$

$$\mathrm{GDP}_{it} = \beta_0 + \sum_{i=1}^{k} \beta_1 \mathrm{GDP}_{it-1} + \sum_{i=1}^{k} \beta_2 \mathrm{CO2}_{it-1} + \sum_{i=1}^{k} \beta_3 \mathrm{FDI}_{it-1} + \sum_{i=1}^{k} \beta_4 \mathrm{POP}_{it-1} + \sum_{i=1}^{k} \beta_5 \mathrm{ENR}_{it-1} + \sum_{i=1}^{k} \beta_6 \mathrm{INTE}_{it-1} + \mu_t$$

$$\mathrm{FDI}_{it} = \beta_0 + \sum_{i=1}^{k} \beta_1 \mathrm{FDI}_{it-1} + \sum_{i=1}^{k} \beta_2 \mathrm{CO2}_{it-1} + \sum_{i=1}^{k} \beta_3 \mathrm{GDP}_{it-1} + \sum_{i=1}^{k} \beta_4 \mathrm{POP}_{it-1} + \sum_{i=1}^{k} \beta_5 \mathrm{ENR}_{it-1} + \sum_{i=1}^{k} \beta_6 \mathrm{INTE}_{it-1} + \pi_t$$

$$\mathrm{POP}_{it} = \beta_0 + \sum_{i=1}^{k} \beta_1 \mathrm{POP}_{it-1} + \sum_{i=1}^{k} \beta_2 \mathrm{CO2}_{it-1} + \sum_{i=1}^{k} \beta_3 \mathrm{FDI}_{it-1} + \sum_{i=1}^{k} \beta_4 \mathrm{GDP}_{it-1} + \sum_{i=1}^{k} \beta_5 \mathrm{ENR}_{it-1} + \sum_{i=1}^{k} \beta_6 \mathrm{INTE}_{it-1} + \delta_t$$

4. Presentation of Results

This section will be subdivided into two subsections. The presentation of the results of the preliminary tests will be the subject of the first subsection. The second sub-section will provide an econometric and economic interpretation of the estimation of the causality equation between economic growth and energy consumption.

4.1. Presentation of the Results of the Preliminary Tests

This subsection highlights four types of tests: the result of the stationarity test, the cointegration test, the estimation of the energy consumption equation by the

FMOLS and DOLS methods and the Granger Causality test.

4.1.1. Presentation of the Stationarity Test

Unlike first generation unit root tests such as Levin, Lin, & Chu (2002) and Im, Pesaran, & Shin (2003), the null hypothesis of Hadri's stationarity test assumes the absence of a unit root (the series is stationary).

Table 1 summarizes the results of the (LLC), (IPS), (BRT), (MW), Hadri's test as well as the Heteroscedasticity test applied on the different variables of the model. The results of Hadri's stationarity test indicate that all variables are non-stationary at the level (or stationary in first difference). Economically, the presence of the unit root (the series is non-stationary) means that the evolution of these variables is affected by temporal factors. Since the variables are integrated at the same order, we will proceed to the cointegration test.

4.1.2. Cointegration Test

The verification of the non-stationarity properties for all the variables of the panel leads us to study the existence of a long term relationship between these variables, i.e. the study of the existence of a cointegration relationship, by applying the Pedroni cointegration tests which are based on unit root tests on estimated residuals. The results of the estimation are presented in Table 2 below.

From the results of Pedroni's cointegration tests, we can see that out of the six statistics, five have probability values below 5%. These are mainly (panel rho-statistic), (Panel pp-Statistic) as well as (panel ADF-statistic) for what concerns the intra-individual tests and we also have (Group PP-Statistic) and (Group p-Statistic) for the inter-individual tests. Thus, all these tests show the existence of a cointegration relationship.

In the presence of cointegration, techniques such as FMOLS (FullyModifiedOrdinary Least Square), DOLS (Dynamic Ordinary Least Square) and PMG/ARDL (PooledMean Group) are recommended. Methods for estimating cointegrating relationships such as Fully Modified Ordinary Least Square (FMOLS) or Dynamic Ordinary Least Square (DOLS) for panel data require that all variables are integrated of order one. Since all our variables are integrated at order one, we have opted in this study to use the fully modified ordinary least squares (FMOLS) method. In addition, we have mobilized the dynamic ordinary least squares (DOLS) method for robustness purposes.

4.2. Presentation of the Results of the Estimations

4.2.1. The Effect of Economic Growth on Energy Consumption in the CEMAC Zone

The table below gives the results of the estimation of our econometric model. To test the robustness (sensitivity) of our results, we used the Fully Modified Ordinary Least Square (FMOLS) and DOLS methods for previous reasons (non-stationary panel and presence of a cointegration relationship). The results are presented in Table 3 below.

Table 1. Result of Hadri's stationarity test.

Null: Unit Root							Null: NO Unit Root	
Methods		Levin, Lin andChu (LLC)	Breitung t-stat	Im, Pesaran And Shin (IPS) W-stat	MW – ADF FisherChi-square	MW – PP FisherChi-square	Hadri Z-stat	Heteroscedastic consistent Z-stat
	Variables							
Level	Log ENR	−0.58547 (0.2791)	−0.86527 (0.1934)	−0.28302 (0.3867)	10.9294 (0.5350)	14.1294 (0.2995)	6.30638*** (0.0000)	4.28922*** (0.0000)
	Log PIB	0.32908 (0.6290)	0.35172 (0.6375)	1.10111 (0.8646)	5.51230 (0.9386)	6.51064 (0.8882)	6.69188*** (0.0000)	6.24581*** (0.0000)
	Log IDE	−8.013*** (0.0000)	2.05532 (0.9801)	−5.27*** (0.0000)	76.01*** (0.0000)	8.55573 (0.7403)	4.051*** (0.0000)	6.55*** (0.0000)
	Log CO_2	−0.45952 (0.3229)	−0.56528 (0.2859)	0.04794 (0.5191)	9.95158 (0.6202)	12.2761 (0.4238)	6.73*** (0.0000)	4.82*** (0.0000)
	Log POP	−4.36020 (0.3206)	1.39135 (0.9179)	−1.415* (0.0785)	16.7607 (0.1588)	37.59*** (0.0000)	3.41656*** (0.0003)	2.19112 (0.0142)
	Log INTE	−3.558*** (0.0002)	−2.71*** (0.0033)	−2.65*** (0.0039)	27.08*** (0.0075)	47.03*** (0.0000)	6.05840*** (0.0000)	4.45178*** (0.0000)
First difference	Δ Log ENR	−8.909*** (0.0000)	−9.65*** (0.0000)	−11.4*** (0.0000)	120.84*** (0.0000)	213.7*** (0.0000)	1.04087 (0.1490)	1.27951 (0.1004)
	Δ Log PIB	−5.80*** (0.0000)	−3.09*** (0.0010)	−5.93*** (0.0000)	55.78*** (0.0000)	115.09*** (0.0000)	1.52939* (0.0631)	0.43618 (0.3314)
	Δ Log IDE	−6.134*** (0.0000)	−0.41770 (0.3381)	−10.2*** (0.0000)	109.28*** (0.0000)	31.85*** (0.0015)	−1.09847 (0.8640)	2.04999** (0.0202)
	Δ Log CO_2	−6.49*** (0.0000)	−9.73794 (0.2836)	−11.7*** (0.0000)	124.9*** (0.0000)	213.0*** (0.0000)	1.19004 (0.1170)	1.59743* (0.0551)
	Δ Log POP	−4.729*** (0.0000)	−3.31***(0.0005)	−11.4*** (0.0000)	120.9*** (0.0000)	167.5*** (0.0000)	3.334*** (0.0004)	5.293*** (0.0000)
	Δ Log INTE	−12.6*** (0.0000)	−6.07*** (0.0000)	−13.5*** (0.0000)	148.4*** (0.0000)	367.8*** (0.0000)	5.323*** (0.0000)	10.98*** (0.0000)

Source: Authors using EViews 9 software; ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Δ is the first difference operator. Values in parentheses represent probabilities.

Table 2. Result of the Pedroni cointegration test.

Methods	Within dimension (panel statistics)			Between dimension (individuals statistics)		
	Test	Statistique	Prob	Test	Statistique	Prob
Pedroni (1996)	**Panel v−statistic**	−3.653972	0.9999	**Group ρ−statistic**	−6.6690 ***	0.0000
	Panel rho−statistic	−7.910 ***	0.0000	**Group pp−statistic**	−10.878***	0.0000
	Panel PP−statistic	−11.148***	0.0000	**Group ADF−statistic**	−1.095872	0.1366
	Panel ADF−statistic	−1.625178*	0.0521			
Pedroni (2004) (Weighted statistic)	**Panel v−statistic**	−3.654024	0.9999			
	Panel rho−statistic	−7.6794***	0.0000			
	Panel PP−statistic	−10.176***	0.0000			
	Panel ADF−statistic	−3.0392***	0.0012			

Source: Authors using EViews 9 software. ***, **, and * indicate significance at 1%, 5%, and 10%, respectively. The values in parenthesis represent the probabilities.

Table 3. Effect of economic growth on energy consumption.

Dependent variable: Energy consumption (lnENR)		
	FMOLS	DOLS
lnPIB	5.87*** (0.00)	3.70*** (0.000)
lnIDE	−9.15*** (0.00)	−6.24*** (0.00)
$lnCO_2$	16.52*** (0.00)	14.70*** (0.00)
lnPOP	2.08** (0.00)	0.84 (0.4)
lnINTE	−5.47*** (0.00)	−4.27*** (0.00)
R^2	0.83	0.88
Ajusted R^2	0.77	0.81

Source: Authors using EViews 9 software. ***, **, and * indicate significance at 1%, 5%, and 10%, respectively. The values in parenthesis represent the probabilities.

The table above establishes the long-run elasticity between the different variables of the model using the FMOLS and DOLS estimators for the panel of CEMAC countries (the coefficients can be interpreted as the elasticity, because the variables are expressed in natural logarithms).

The modeling of the within dimension allows us to take into account the heterogeneity of individuals in their temporal and/or individual dimension. The within estimator eliminates individual specific effects (persistent differences between countries over the period); it favors temporal information.

All the estimated coefficients of the within dimension indicate that GDP, CO_2, and POP are positively correlated except the coefficient of FDI and INTE which are negatively and significantly correlated with energy consumption at the 5% threshold (first column of the table).

Overall, the results of regressing the explanatory variables GDP, CO_2, FDI, INTE and POP on ENR in the Within dimension using the FMOLS panel data estimator reveal a strong long-run relationship between the exogenous variables in our model and the endogenous variable ENR, and also show the importance of all these variables in explaining energy consumption in these countries. Unlike the use of the DOLS estimator in this same dimension we accept at the 5% level the significance of the coefficients of four variables, i.e., GDP, FDI, CO_2, and INTE. This is evidence that our results are robust.

The estimation of the energy consumption equation in the CEMAC zone by the Fully Modified Ordinary Least Squares method shows that the variables GDP, FDI, CO_2, INTE and POP are significant at the 1 and 5% levels respectively.

GDP has a positive and significant effect on energy consumption. Thus, an increase in GDP of 1% leads to an increase in the energy consumption-GDP elasticity of 5.87%. This result can be explained by the fact that an increase in national wealth leads to an increase in energy consumption demand. This result is consistent with the work of Bartleet & Gounder (2010) who showed a positive and significant relationship of economic growth on energy consumption for Nigeria.

FDI has a negative and significant effect on energy consumption in the CEMAC zone. This result can be explained by the fact that most of the FDI received by CEMAC countries is not concentrated in energy-intensive sectors such as the services sector (finance, insurance and trade).

Furthermore, the energy consumption-CO_2 elasticity is 16.52%. This means that any increase in the level of CO_2 leads to an increase in energy consumption. This result can be explained by the fact that most of the pollution is generally caused by human activities. These activities are generally dependent on production or services such as transportation that require a high energy consumption.

The energy consumption population elasticity is 2.08%. This means that the increase in population increases the demand for energy consumption. This result can be explained by the fact that population growth leads to an increase in demand for goods and services. The companies that adjust their offer to satisfy the new demands, consume more energy.

The energy consumption-energy intensity elasticity is −5.47%. This inverse relationship can be explained by the fact that with the advent of renewable energies, an increase in energy intensity will inevitably lead to a reduction in the consumption of fossil fuels.

Apart from the coefficient of the population variable which is not significant, the other variables of the model are significant and keep their signs with the use of the DOLS method. In general, this means that our estimate is robust. It should be noted that the CEMAC zone has negative and significant results for some variables such as: FDI and INTE in the Within dimension. On the other hand, for the rest of the variables, the coefficients are positive and statistically significant at the 1% and 5% thresholds for both the FMOLS and DOLS methods, except for the POP variable for the DOLS method.

These results highlight the participation of the different variables in the overall primary energy consumption. It should be noted that this same panel has significant and sometimes different tests when passing from the FMOLS method to the DOLS method. Therefore, its results should be taken with the utmost reserve.

4.2.2. Granger Causality Test

In the presence of a long term relationship between GDP, FDI, CO_2, POP, INTE and ENR, the next step is to test the causality links between these variables using the Granger causality test in panel. A Granger causality analysis is performed to determine if there is potential predictability power from one indicator to another. The results of the Granger causality test for all individuals are summarized in the following table. Note that the optimal lag was established using the Akaike and Schwarz information criteria (**Table 4**).

Table 4. Result of the Granger causality test.

Lags = 7	ENR	PIB	IDE	CO_2	POP	INTE
ENR	✕	2.32555* → (0.0994)	0.11089 ▭ (0.8951)	0.54341 ▭ (0.5813)	6.71774*** → (0.0014)	0.88005 ▭ (0.4158)
PIB	7.28106*** → (0.0008)	✕	0.20124 ▭ (0.8178)	5.90217*** → (0.0030)	0.16348 ▭ (0.8493)	0.64903 ▭ (0.5233)
IDE	1.75138 ▭ (0.1754)	5.94718*** ▭ (0.0029)	✕	022452 ▭ (0.7990)	0.01020 ▭ (0.9899)	0.57480 ▭ (0.5635)
CO_2	1.47918 ▭ (0.2294)	5.90217* ▭ (0.0778)	0.33961 ▭ (0.7123)	✕	5.88043*** → (0.0031)	1.26196 ▭ (0.2846)
POP	2.40333* → (0.0921)	2.08090 ▭ (0.1266)	0.13871 ▭ (0.8705)	2.13991 ▭ (0.1194)	✕	5.08321*** → (0.0067)
INTE	2.57398* → (0.0779)	2.51881* → (0.0822)	0.02944 ▭ (0.9710)	1.95002 ▭ (0.1440)	0.94060 ▭ (0.3915)	✕

Source: Authors using EViews 9 software. ***, **, and * indicate significance at 1%, 5%, and 10%, respectively. The values in parenthesis represent the probabilities. ▭ Absence of causality. → unidirectional causality.

Our study aims to illustrate the interactive relationships between the set of variables GDP, FDI, CO_2, POP, INTE and ENR, but this does not prevent the study of all possible relationships. From the results of the Granger tests presented in the table above, we can deduce the direction of the causal relationships that may exist between the variables at the critical threshold (1%, 5% and 10%). The results indicate that a bidirectional causality exists between ENR and GDP. Therefore, the feedback hypothesis is verified between GDP and energy consumption. On the other hand, we note another bidirectional causality between ENR and POP. Moreover, we have noted a unidirectional causality between GDP and CO_2 (GDP → CO_2); between CO_2 and POP (CO_2 → POP); between POP and INTE (POP → INTE); between INTE and GDP (INTE → GDP) and between INTE and ENR (INTE→ ENR) in the CEMAC zone.

5. Conclusion and Policy Implications

One of the main concerns of development is access to energy. Today, a large proportion of people do not have access to "modern" aspects of energy such as electricity and renewable energy. Traditional fuels meet the majority of energy demand, which unfortunately are very inefficient, and above all cause significant health problems and air pollution. In this article, we have examined the direction of causality linking economic growth and energy consumption. After establishing the long-run relationship between GDP and energy consumption, we applied the FMOLS and DOLS estimation methods, estimators proposed by Pedroni (2001) and Mark & Sul (2003). The estimation of the energy consumption equation in the CEMAC zone by the FMOLS showed that GDP significantly increased energy consumption. Furthermore, by applying the Granger causality test, the results indicated the existence of a bidirectional causality between economic growth and energy consumption in the CEMAC zone. This validates the retroactivity hypothesis.

In view of its growing energy needs and with a view to preserving the environment through rational management of natural resources, the CEMAC zone must implement an energy efficiency policy based on the use of new technologies (biomass, hydrogen, wind, solar) to the detriment of the current fossil energy policy applicable today. Indeed, the implementation of this energy strategy will promote the attractiveness of external funding for the conservation of natural resources but also trigger investment in the renewable energy sector which is a potential asset recorded in this area.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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