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Access to Electricity and Economic Growth in the WAEMU: Causality Analysis

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Abstract

The objective of this paper is to determine the possible link between economic growth and electricity access rate. An autoregressive lag model (ARDL) on panel data from 1998 to 2019 for West African Economic and Monetary Union (WAEMU) member states was used. This model shows that in long term, the growth rate has a positive impact on access to electricity in WAEMU member states. In the short term, economic growth rate has a positive and significant impact on electricity access rate only in Benin. The results of Granger causality test show an unidirectional relationship from GDP growth rate, investment rate to access to electricity.

Keywords: access to electricity, economic growth, causality, panel data

JEL: L94; O47; C12; C33

1. Introduction

West African Economic and Monetary Union (WAEMU) was created on 10 January 1994 in Dakar, establishing an economic area within free movement of people, capital, goods, services and factors of production is ensured. It is composed with Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal and Togo. It covers an area of 3,506,126 km2 and has 123.6 million inhabitants. This economic and monetary integration implies a strong interdependence between the union countries. Indeed, the economic growth of one of countries' member is certainly conditioned by another member state or other member states. The strong energy interdependence between some countries of the union can be an advantage or disadvantage for them. Indeed, Côte d'Ivoire exports electricity to Burkina Faso and Mali. In addition, the membership of WAEMU countries in West African Power Pool, that is *an institution that aims to integrate national power systems into a unified regional electricity market,* increases their dependence each other. Knowing that electricity essentially plays two fundamental roles: as intermediate consumption in production of goods and services, and as final consumption for lighting and the use of household appliances, its contribution to economic growth and the improvement of household welfare in the union is more essential.

The upward trend in economic growth rate in the States (Côte d'Ivoire: 0.81% in 1994 and 6.23% in 2019, Niger: 1.85% in 1994 and 5.94% in 2019, Senegal: -0.05 in 1994 and 7.4% in 2017, source: World development indicator 2022) should be able to raise the level of per capita income of population and also lead to an increase in access to electricity for households, as they will be able to bear the cost of subscriptions and electricity bills. Also, it is important to note that the increasing in per capita income may lead households to purchase appliances such as household appliances and televisions that run on electricity. This can increase the demand for electricity and lead to an increase in electricity production and even an increase in the wealth of the members of Union. In order to support the possible link between these variables with calculations, it is important to distinguish between developed and developing countries. From the data in tables 1, 2, 3 and 4 in the appendix, we calculate covariances and correlation coefficients confined in the table 5 of the appendix.

The null value of the covariance and correlation coefficient for the data in tables 1 and 4 demonstrates that there is no link between the growth rate and rate of access to electricity in developed countries, regardless of the nature of data (time series or cross-sectional data) on the one hand. On the other hand, the values 7.73 and -2.81 of covariance respectively in Côte d'Ivoire for time series and in WAEMU countries for cross-sectional data, highlight the existence of link between economic growth and the rate of access to electricity. Then, an observation of correlation coefficients -0.18 and 0.42 reveals that in Côte d'Ivoire, from a time series, the degree of correlation between the growth rate and rate access to electricity is little higher (0.42), contrary to the case where we have cross-sectional data from WAEMU countries (-0.18). From the above, it appears to establish a link between economic growth and household access to electricity. This raises some key questions: in what sense do we have this link? How do we quantify the link between economic growth and electricity access? What about the link in the short term and long term?

Unfortunately, this descriptive approach the link between the growth rate and rate access to electricity cannot inform us about the type of causality between both variables. Is it unidirectional, bidirectional or neutral? In order to determine the type of causality between these variables, we adopt the following plan: 2) literature review which presents the works related to our subject. 3) methodology which presents the econometric model that we have chosen to research the type of causality between these variables and 4) conclusion which summarises and gives the major results of our study. Then, 5) bibliographical references that enabled us to carry out our study.

2. Review Literature

This articles mainly presents work that deals with the link between energy consumption and economic growth. However, it was not possible to identify articles that address link between economic growth and access rate. This is because the rate of access precedes electricity consumption, i.e. one must have access to electricity before consuming it. First, we present some of the work that links energy consumption to economic growth. Secondly, we discuss studies that show link between electricity consumption and economic growth.

The energy crises of the 1970s and 1980s led to several studies on the relationship between energy consumption and economic growth. Ayres (1978) discusses relationship between energy and economic growth in the long term based on energy transitions. As for Kraft & Kraft (1978), they study the structural changes corresponding to energy transitions observed in an energy balance of nations.

The work developed on this subject has definitively established the relationship between energy demand and economic growth. However, it has not established the nature of relationship between energy and economic growth.

More recently, time series studies have attempted to determine the type of causality between economic growth and energy. Indeed, is this relationship unidirectional, bidirectional or neutral? The work of Ozturk (2010), Ghali et al (2004) and Chontanawat et al (2008) does not allow us to decide between the different types of causality mentioned above. Also, several studies address the causal relationship between Gross Domestic Product (GDP) and energy consumption to analyse the main effects of the various contemporary energy crises on development (Erdal et al., 2008; Hu and Lin, 2008; Belloumi, 2009; Ouédraogo, 2010; Lorde et al., 2010; Iwayemi et al., 2010; Sharma, 2010).

In Sub-Saharan Africa, the reflections of Akinlo (2008) and Mensah (2014) lead to non-determination of type of causality between economic growth and energy. Mensah shows that energy consumption unidirectionally determines economic growth in Kenya, while in Ghana this relationship is true in the opposite direction On the one hand. Economist Wolde-Rufael (2009), on the other hand, arrives at a more nuanced result. He uses a multivariate analysis, incorporating capital and labour alongside energy to explain growth.

Specifically, some studies focus on the relationship between electricity consumption and economic growth. Indeed, in the case of unidirectional causality of electricity to GDP, studies cover different countries and use Granger causality to highlight the fact that electricity sector can be limited or accelerating factor of economic growth (Ramcharran, 1990; Altinay and Karagol, 2005; Ho and Siu, 2007; Aqeel and Butt, 2008; Yuan et al., 2008, Yang Chen and Zheng Fang, 2018).

In the case of unidirectional causality from GDP to electricity, it appears that GDP is not explained by electricity (Ghosh, 2002; Jumbe, 2004; Narayan and Smyth, 2005; Yoo and Kim, 2006; Mozumder and Marathé, 2007; Halicioglu, 2007, Hu and Lin, 2008; Gosh, 2009). In contrast, Wehbe et al (2018) show that in Lebanon, there is a unidirectional causality, for the period (1990-2012), from electricity consumption to economic growth.

In the case of bidirectional causality, electricity explains economic growth and conversely, GDP leads to an increase in energy consumption. In this case, there is a two-way relationship between the two factors which are closely linked (Yang, 2000; Yoo, 2005; Zachariadis and Pashouortidou, 2007; Tang, 2008; Odhiambo, 2009b; Narayan and Smyth, 2009). The absence of causality between the electricity sector and GDP, showing a neutral hypothesis, has been demonstrated by some economists such as: (Murray and Nan, 1996; Chen et al., 2007).

The analysis of empirical data reveals that the relationship between electricity consumption and GDP is not clearly identified. The contradictory results can be explained by different time periods chosen, methods of estimating cointegration and causality and/or the set of variables.

3. Methodology

The methodology chosen to analyse the possible link between the rate of access to electricity and economic growth is staggered lag autoregressive model (ARDL). This choice is justified by the fact that this model makes it possible to capture the short-term dynamics and long-term effects of one or more explanatory variables on a variable to be explained.

We estimate two models by Pool Mean Group (PMG) and Mean Group (MG) regression in long and short run which take general forms:

$$\text{Model 1: } AELEC_{it} = \sum_{j=1}^{p} a_{ij} AELEC_{i,t-j} + \sum_{j=0}^{q} b_{ij} PIBGROWTH_{i,t-j} + u_i + e_{it}$$

Model 2:

$$AELEC_{it} = \sum_{j=1}^{p} c_{ij} AELEC_{i,t-j} + \sum_{j=0}^{q} d_{ij} \log\_PIB100_{i,t-1} + \sum_{j=0}^{q} \alpha_{ij} \log\_CELEC_{i,t-j} + \sum_{j=0}^{q} \beta_{ij} TAUINVEST_{i,t-j} + \sum_{j=0}^{q} \delta_{ij} POLISTAB_{i,t-j} + \varphi_i + \rho_{it}$$

With u_i and φ_i: constants that differ from country to country. e_{it} and ρ_{it}: the error terms. The variables is given as follows:

3.1 Variables Specification

We estimate two models which are model 1 and model 2.

In model 1, we have two variables:

- The rate of access to electricity (AELEC) which is the explained variable, it represents the percentage of population of electrified localities compared to the total population of the country, to a given period;

- The rate of economic growth (GDPGROWTH), is the explanatory variable. It indicates the relative percentage change in Gross Domestic Product (GDP) of a country in a given year.

In model 2, we have five variables. In addition to the rate of access to electricity (AELEC) which is the dependent variable, we take into account four independent variables which are

- The rate of investment (TAUINVEST) which represents the percentage of the Gross Fixed Capital Formation of a country in relation to its GDP for a given year;

- Electricity consumption (CELEC) which is the total amount of kilowatt-hours consumed by all electricity users in a given year in a given country. For convenience, we replace the CELEC variable by its logarithm: log_CELEC;

- The political stability index (POLISTAB) which represents political stability. It measures, for a given country, perceptions of the possibility of political violence, including terrorist acts. The higher the score, the better the situation;

- The variable log_PIB100 which is given by adding 100 to the GDP growth rate to eliminate all negative values and then determining the logarithm of the resulting sum.

3.2 Hypotheses

The first assumption is that economic growth has a positive impact on access to electricity. The second assumption is that there is a bidirectional relationship between electricity consumption and access to electricity. The third hypothesis is that there is unidirectional relationship between the investment rate and access to electricity. The fourth and final hypothesis is that there is a unidirectional relationship between the political stability of WAEMU member states and access to electricity.

3.3 Empirical Framework

The data we use are extracted from the World Bank database (WDI: World Development Indicators 2022) and the BCEAO (Central Bank of West African States) database available on its website. They cover the period from 1998 to 2019 for seven (7) member countries of the West African Economic and Monetary Union (WAEMU). Guinea Bissau has been removed from the database due to a serious lack of data on access rates. In addition, the estimates are conducted using STATA.15 software. The following table gives the descriptive statistics of our data:

Table 6. Descriptive statistics of data

Variables	**Observations**	**Mean**	**Std error**	**Minimum**	**Maximum**
AELEC	154	31.5899	18.26	6.066864	70.4
Log_PIB100	154	4.648773	0.0292825	4.54997	4.748199
Log_CELEC	154	13.75132	0.8937043	12.30042	15.90162
TAUINVEST	154	19.76233	5.420222	10.5	32.62
POLISTAB	154	-0.4670438	0.7184365	-2.264047	0.8202942

Source: Author

According to the statistics in the table above, the rate of access to electricity is a very volatile variable around the mean (standard deviation: 18.26). As for the variables log_PIB100, log_CELEC and POLISTAB, they each have a low standard deviation. This reflects a low dispersion of these variables around their respective means. The investment rate, however, has a slightly high standard deviation. This expresses a strong difference between the levels of investment over the years and in the different WAEMU countries.

It is important to note that the variables selected must be stationary to avoid spurious regression. To test the stationarity of our data, we use the following tests: The Levin, Lin and Chu (2002) test, the Breitung (2000) test, the Im, Pesaran and Shin (2003) test. All these tests are inspired by the Augmented Dickey-Fuller (ADF) test of Dickey and Fuller in time series. Also, we test the cointegration of access to electricity with the other variables using the test of Kao (1999) which tests the stationarity of the estimated residuals of the long term relationship and that of Westerlund (2007) which develops four tests of cointegration based, not on the residuals of the long term relationship, but, on the validation of an error correction mechanism will be applied.

After having verified the stationarity of the variables and the existence of the cointegrating relationship, the models will be estimated using the Pooled-Mean Group (PMG) and Mean Group (MG) methods when the WAEMU countries are considered as a block or are taken separately. Subsequently, using the Hausman test, we will choose between the PMG and the MG.

Furthermore, using the Granger (1987) test, we will verify the causality between the rate of access to electricity and the rate of growth in the short term and in the long term.

3.3.1 Tests for Stationarity and Cointegration of Variables

Table 7 presents the results of the stationarity tests for model 1 and table 8 presents those for model 2. Table 9 and 10 give the results of the cointegration tests for model 1 and model 2 respectively:

Table 7. Results of stationarity tests (model 1)

TEST	VARIABLES	AT LEVEL I(0)		I(1)	
		without trend	With trend	Without trend	With trend
LLC (Levin, Lin et Chu)	AELEC	6.6833 (1.0000)	-1.7322 (0.0416)*	-6.2472 (0.0000)*	-4.2917 (0.0000)*
	PIBGROWTH	-2.0901 (0.0183)*	-3.5592 (0.0002)*	-12.8057 (0.0000)*	-5.7823 (0.0000)*
IPS (Im, Pesaran et Shin)	AELEC		-5.3547 (0.0000)*		-6.9699 (0.0000)*
	PIBGROWTH		-6.1557 (0.0000)*		-7.1713 (0.0000)*
Breitung	AELEC	4.4426 (1.0000)	-5.2109 (0.0000)*	-8.6822 (0.0000)*	-6.9563 (0.0000)*
	PIBGROWTH	-3.2501 (0.0006)*	-5.3663 (0.0000)*	-9.7117 (0.0000)*	-7.5286 (0.0000)*

Source : Author (estimation results)

The data contained in Table 7 are, for each test, the calculated statistics and between the brackets we have the p-value. When the p-value is below 0.05 (values with *), the hypothesis H0: of non-stationarity is rejected and the hypothesis H1: of existence of stationarity is accepted at the 5% threshold. In our case, in the absence of a trend and at level, access to electricity is non-stationary, but the growth rate is. At level and in the presence of a trend or in 1st difference (without trend or with trend), access to electricity and the growth rate are stationary. In the end, we find that our variables are stationary. Table 8 below shows the results of the stationarity tests carried out on the variables of model 2:

Table 8. Results of stationarity tests (model 2)

TEST	VARIABLES	AT LEVEL I(0)		In difference 1st I(1)	
		Sans trend	Avec trend	Sans trend	Avec trend
LLC	Log_CELEC	5.1707 (1.0000)	-0.0885 (0.4647)	-5.2353 (0.0000)*	-3.9261 (0.0000)*
	TAUINVEST	1.3006 (0,9033)	-0.6748 (0.2499)	-9.6895 (0.0000)*	-4.2253 (0.0000)*
	POLISTAB	-1.6825 (0.0462)*	-4.8575 (0.0000)*	-8.3299 (0.0000)*	-3.9616 (0.0000)*
IPS	Log_CELEC		-0.8017 (0.2114)		-4.2189 (0.0000)*
	TAUINVEST		-3.1073 (0.0009)*		-5.7829 (0.0000)*
	POLISTAB		-2.9187 (0.0018)*		-3.8969 (0.0000)*
Breitung	Log_CELEC	6.7662 (1.0000)	2.4837 (0.9935)	-6.1097 (0.0000)*	-5.2143 (0.0000)*
	TAUINVEST	0.8954 (0.8147)	-1.8101 (0.0351)*	-8.5337 (0.0000)*	-4.5871 (0.0000)*
	POLISTAB	-1.1804 (0.1189)	-1.0895 (0.1380)	-8.3605 (0.0000)*	-7.7585 (0.0000)*

Source : Author (estimation results)

The previous table gives the calculated statistics and their probability in brackets. The probabilities with asterisks are lower than 0.05 and give the stationary variables at level or in 1st difference. We note that in 1st difference all three variables are stationary with or without trend for the three tests. On the other hand, at level, the LLC test shows that the political stability index is stationary with or without trend. The IPS test shows the stationarity of the political stability index and the investment rate in the presence of a trend. The Breitung test shows the stationarity of the investment rate in the presence of a trend. Finally, we find that all three variables are stationary. The following table gives the results of the Kao and Westerlund cointegration tests. This table does not show the results of the stationarity tests of the variable log_PIB100 because we have already shown in table 7 that the variable GDPGROWTH is stationary which means that the variable log_PIB100 is also stationary.

Table 9. Cointegration test results for model 1

		Statistics		**p-values**
KAO	Modified Dickey-Fuller t	1.7339		0.0415*
	Dickey-Fuller t	1.9728		0.0243*
	A. Dickey-Fuller t	3.9745		0.0000*
	Unadjusted modified Dickey-Fuller t	0.2072		0.4179
	Unadjusted Dickey-Fuller t	0.1927		0.4236
Westerlund	**Statistiques**	**value**	**z-value**	**p-value**
	Gt	-4.731	-7.823	0.000*
	Ga	-30.265	-7.305	0.000*
	Pt	-.212	-3.054	0.001*
	Pa	-23.998	-6.664	0.000*

Source : Author (estimation results)

The first three p-values (0.0415, 0.0243 and 0.0000), for the Kao test, being lower than 0.05, the

hypothesis H0: of the absence of cointegration is rejected and the hypothesis H1: of the existence of cointegration between the variables is retained. With regard to the Westerlund test, the p-values below 0.05 of the four (4) statistics (Gt, Ga, Pt, Pa) show that the rate of access to electricity and the rate of growth are cointegrated, i.e. they depend on each other. Thus, cointegration reflects a strong dependence between WAEMU member countries following an external shock.

Table 10. Cointegration test results for model 2

		Log_CELEC	**TAUINVEST**	**POLISTAB**
KAO	Modified Dickey-Fuller t	1.8939 (0.0291)*	2.3621 (0.0091)*	2.4813 (0.0065)*
	Dickey-Fuller t	2.3825 (0.0086)*	3.0816 (0.0010)*	3.4488 (0.0003)*
	A. Dickey-Fuller t	3.3717 (0.0004)*	3.8655 (0.0001)*	4.1807 (0.0000)*
	Unadjusted modified Dickey-Fuller t	-1.9520 (0.0255)*	0.5136 (0.3038)	0.5430 (0.2936)
	Unadjusted Dickey-Fuller t	-1.1275 (0.1298)	0.2752 (0.3916)	0.3753 (0.3537)
Westerlund	Gt	-3.898 (0.000)*	-6.039 (0.000)*	-4.448 (0.000)*
	Ga	-9.432 (0.837)	-20.634 (0.000)*	-30.446 (0.000)*
	Pt	-9.542 (0.000)*	-4.199 (0.947)	-7.667 (0.008)*
	Pa	-26.468 (0.000)*	-15.122 (0.003)*	-22.301 (0.000)*

Source : Author

The two cointegration tests carried out demonstrate the cointegration of each of the variables with the rate of access to electricity. Indeed, for the Kao test, at least three out of five statistics calculated give p-values lower than 0.05 at the 5% threshold. As for the Westerlund test, out of four statistics calculated, at least three have a p-value below 0.05.

3.3.2 Model Estimation

We estimate our two models by the PMG (Pool Mean Group) and MG (Mean Group) methods. First, Table 10 gives the results of a global estimation in the long term and in the short term of the two models. Secondly, Table 11 shows the short-term and long-term estimation, for each country, by the PMG and MG methods. Finally, Table 12 presents the results of the Granger causality test between the rate of access to electricity and the rate of economic growth and the Hausman test, the results of which lead to the PMG method being the best estimation method.

Table 11. Global model estimation results

Model 1 dependent variable:: AELEC	**PMG**	**MG**
Long-term coefficients		
PIBGROWTH	1.664423 (0.000)*	0.2462049 (0.895)
Short term coefficient		
ECT	-0.0814329 (0.012)*	-0.0926781 (0.005)*
PIBGROWTH	0.02958 (0.684)	0.0889189 (0.443)
CONSTANT	3.72971 (0.0041)*	4.602033 (0.015)*
Model 2: Dependent variable: AELEC		
Long-term coefficients		
Log_PIB100	11.55257 (0.520)	6.799094 (0.718)
Log_CELEC	6.134295 (0.000)*	12.75596 (0.001)*
TAUINVEST	0.0531659 (0.457)	0.4573357 (0.104)
POLISTAB	-0.4245305 (0.589)	-3.544057 (0.140)
Short-term coefficients		
ECT	-0.3434466 (0.023)*	-0.7188719 (0.000)*
Log_PIB100	5.48426 (0.506)	5.236489 (0.654)
Log_CELEC	-4.680541 (0.352)	-6.862367 (0.045)*
TAUINVEST	-0.966454 (0.033)*	-0.2562046 (0.002)*
POLISTAB	-0.7722368 (0.752)	0.2295993 (0.898)
CONSTANT	-38.31612 (0.047)*	-124.745 (0.069)

Source: Author

In Model 1, the results given by the PMG method state that in the long run, the growth rate has a significant positive impact (coefficient=1.664423; p = 0.000) on the rate of access to electricity. However, in the short run, the impact of the growth rate on the rate of access to electricity is not significant (p = 0.684 > 0.05). The present model is acceptable because the ECT recall force has a negative coefficient (-0.0814329) and is significant (p = 0.012). As for the estimation by the MG method, it shows that in the long run the economic growth rate has a positive but not significant impact on the rate of access to electricity (coefficient = 0.2462049 and p = 0.895). In the short term, the MG method also leads to a positive but not significant impact of the economic growth rate on the rate of access to electricity. The model is still acceptable because its recall force is negative with a probability of less than 0.05 (ECT = -0.0926781, p = 0.005).

The estimation of model 2, by both methods (PMG and MG) shows that in the long run electricity consumption has a significant positive impact on the rate of access to electricity (coefficient = 6.13425, p = 0.0000 < 0.05 and coefficient =12.75596, p = 0.001). As for the GDP growth rate and the investment rate, both methods (PMG and MG) show that they have, in the long run, a positive but not significant impact on the electricity access rate (PMG: coefficient of log_PIB100 = 11. 55257 with p = 0.520 > 0.05 and coefficient of TAUINVEST = 0.053165 with p = 0.457 > 0.05, MG: coefficient of log_PIB100 =6.799094 with p = 0.718, coefficient of TAUINVEST = 0.4573357, p = 0.104) The political stability index is, for both methods, in the long run, inversely related to the rate of access to electricity but this relationship is not significant. In the short run, the models are acceptable because, for both methods, they have negative recall forces and probabilities below 0.05. The inverse relationship between the investment rate and the electricity access rate is significant for both methods. For the MG method, electricity consumption (log_CELEC) also shows a significant inverse relationship with the electricity access rate. Therefore, an estimation by both methods taking into account each country is made. The results are confined in the following table:

Table 12. Model estimation results by country

	BENIN		BURKINA FASO		CÔTE D'IVOIRE		MALI		NIGER		SENEGAL		TOGO	
							Dependant variable: AELEC							
Model 1	PMG	MG	PMG	MG	PMG	MG	PMG	MG	PMG	MG	PMG	MG	PMG	MG
Coef LT														
PIBGROWTH	1.664423 (0.000)*	-8.335775 (0.477)	1.664423 (0.000)*	0.0018031 (1.000)	1.664423 (0.000)*	1.541839 (0.003)*	1.664423 (0.000)*	-4.187269 (0.851)	1.664423 (0.000)*	3.144215 (0.221)	1.664423 (0.000)*	5.123457 (0.703)	1.664423 (0.000)*	4.435165 (0.576)
Coef. CT														
ECT	-0.0425861 (0.635)	-0.079395 (0.390)	-0.0944703 (0.322)	-0.1247146 (0.315)	-0.2621419 (0.015)*	-0.2753535 (0.024)*	-0.0160244 (0.819)	-0.0258742 (0.764)	-0.0941627 (0.127)	-0.0738091 (0.296)	-0.0407382 (0.564)	-0.0416664 (0.595)	-0.019907 (0.719)	-0.0279338 (0.666)
PIBGROWTH	0.3069225	0.7200522	-0.1436166	-0.063957	-0.1015844	-.0964429	0.0155946	0.083007	-0.1170532	-0.1543047	0.2941862	0.2234489	-0.0473888	-0.0893713

	(0.307)	(0.052)	(0.323)	(0.786)	(0.441)	(0.511)	(0.927)	(0.794)	(0.063)	(0.052)	(0.367)	(0.609)	(0.761)	(0.661)
CONSTA NT	1.87327 2 (0.358)	6.23645 4 (0.041) *	0.78513 12 (0.144)	2.07777 2 (0.467)	14.4593 4 (0.012) *	15.2501 1 (0.019) *	2.24507 8 (0.104)	3.14724 1 (0.399)	0.92549 82 (0.020) *	0.31178 57 (0.693)	3.51462 2 (0.259)	2.93995 2 (0.461)	2.30502 8 (0.134)	2.25092 1 (0.188)
Dependant Variable : AELEC														
Model 2														
Coef. LT														
Log_PIB1 00	11.5525 7 (0.520)	-54.628 73 (0.707)	11.5525 7 (0.520)	-11.613 64 (0.574)	11.5525 7 (0.520)	90.7738 8 (0.011) *	11.5525 7 (0.520)	12.3391 6 (0.897)	11.5525 7 (0.520)	49.0670 5 (0.583)	11.5525 7 (0.520)	-35.396 55 (0.711)	11.5525 7 (0.520)	-2.9475 07 (0.966)
Log_CEL EC	6.13429 5 (0.000) *	5.32387 4 (0.595)	6.13429 5 (0.000) *	6.47268 9 (0.000) *	6.13429 5 (0.000) *	12.4845 2 (0.003) *	6.13429 5 (0.000) *	1.21190 6 (0.917)	6.13429 5 (0.000) *	10.0206 9 (0.180)	6.13429 5 (0.000) *	26.1318 3 (0.014) *	6.13429 5 (0.000) *	27.6462 3 (0.000) *
TAUINV EST	0.05316 59 (0.457)	0.19571 24 (0.737)	0.05316 59 (0.457)	-0.0934 247 (0.379)	0.05316 59 (0.457)	-0.1003 156 (0.787)	0.05316 59 (0.457)	1.99850 7 (0.043) *	0.05316 59 (0.457)	0.35337 66 (0.645)	0.05316 59 (0.457)	0.77576 79 (0.207)	0.05316 59 (0.457)	0.07172 66 (0.846)
POLISTA B	-0.4245 305 (0.589)	-5.8543 89 (0.557)	-0.4245 305 (0.589)	-0.4901 213 (0.552)	-0.4245 305 (0.589)	-3.4279 86 (0.023) *	-0.4245 305 (0.589)	-10.320 49 (0.090)	-0.4245 305 (0.589)	7.51357 (0.577)	-0.4245 305 (0.589)	-10.922 4 (0.170)	-0.4245 305 (0.589)	-1.3065 83 (0.791)
Coef. CT														
ECT	-0.4686 767 (0.000) *	-0.5024 292 (0.064)	-1.1600 71 (0.000) *	-1.4426 7 (0.000) *	-0.2387 869 (0.102)	-0.8459 331 (0.000) *	-0.0418 179 (0.690)	-0.7111 549 (0.042) *	-0.3971 528 (0.006) *	-0.2657 112 (0.331)	-0.0726 557 (0.256)	-0.5702 957 (0.125)	-0.0249 66 (0.679)	-0.6939 089 (0.019) *
Log_PIB1 00	51.4661 2 (0.022) *	73.1807 1 (0.078)	-6.8352 57 (0.611)	7.69313 8 (0.665)	10.4115 7 (0.488)	-11.849 65 (0.455)	4.81961 7 (0.819)	-13.400 36 (0.778)	-2.2929 21 (0.677)	-9.1463 28 (0.337)	-14.324 86 (0.630)	-11.067 67 (0.816)	-4.8544 62 (0.774)	1.24559 3 (0.969)
Log_CEL EC	-33.704 53 (0.000) *	-22.590 1 (0.193)	6.04811 7 (0.106)	4.09961 7 (0.360)	1.47051 9 (0.721)	-9.5274 15 (0.041) *	-3.6308 56 (0.486)	-1.9137 73 (0.800)	-1.6291 39 (0.325)	-2.3165 54 (0.356)	2.87827 2 (0.772)	-1.8944 66 (0.898)	-4.1961 66 (0.645)	-13.893 88 (0.256)
TAUINV EST	-0.2348 568 (0.171)	-0.2881 671 (0.285)	-0.2230 874 (0.138)	-0.1152 617 (0.522)	-0.0758 574 (0.811)	-0.5728 767 (0.069)	-0.1086 228 (0.814)	-0.5354 274 (0.414)	-0.1444 286 (0.042) *	-0.1372 162 (0.247)	0.09039 28 (0.610)	-0.1584 116 (0.543)	0.01994 25 (0.840)	0.01392 87 (0.936)
POLISTA B	3.90208 7 (0.189)	4.03993 1 (0.462)	1.71213 (0.185)	1.22511 4 (0.435)	0.92820 28 (0.638)	1.05613 8 (0.559)	2.85050 1 (0.310)	4.81297 6 (0.211)	-0.3208 596 (0.667)	-1.2220 49 (0.384)	-15.071 96 (0.000) *	-9.4736 13 (0.179)	0.59424 59 (0.672)	1.16869 9 (0.618)
CONSTA NT	-47.103 02 (0.291)	108.295 1 (0.731)	-144.62 63 (0.149)	-26.577 36 (0.856)	-21.067 01 (0.432)	-471.45 4 (0.001) *	-2.1543 47 (0.864)	-66.949 48 (0.837)	-48.171 85 (0.185)	-92.102 39 (0.255)	-4.5430 33 (0.603)	-103.21 87 (0.616)	-9.5472 392 (0.934)	-221.20 81 (0.309)

Source : Author

These results show that in the short term, taking into account the recall force (ECT) and its probability, the estimation by both methods of model 1 is acceptable for Côte d'Ivoire (PMG: coefficient = - 0.2621419 with p = 0.015, MG: coefficient = - 0.2753535 with p = 0.024). In the long run, the application of the MG method to model 1 gives only for Côte d'Ivoire a significant positive impact of the economic growth rate on the electricity access rate (coefficient of PIBGROWTH =1.541839 with p = 0.003 < 0.05).

It is important to note that the estimation of model 1 and model 2 by the long-run PMG method gives the same results for each of the seven WAEMU countries. As for the estimation of model 2 by the long-term MG method leads to the following results:

- Electricity consumption has a significant positive impact on the rate of access to electricity in Burkina Faso, Côte d'Ivoire, Senegal and Togo;
- The rate of economic growth has a significant positive impact on access to electricity in Côte d'Ivoire;
- In Mali, the investment rate has a significant positive impact on access to electricity;

- In Côte d'Ivoire, the political stability index has a significant negative impact on access to electricity.

The estimation of model 2 in the short term by the two methods gives the following results which we present by country:

- For Benin, the estimation by the MG method does not present any significant coefficient. On the other hand, the estimation by the PMG method gives an acceptability of the model because its recall force is negative and significant (coefficient = - 0.4686767, p = 0.000), then it also exposes a positive significant impact for the economic growth rate (coefficient = 51.46612, p = 0.022) and negative for the electricity consumption (coefficient = - 33.70453, p = 0.000)

- For Burkina Faso, the estimation of model 2 by both methods gives an acceptable regression (PMG: ECT = -1.160071, p = 0.000 and MG: ECT = -1.44267, p = 0.000) but none of the variables is significant;

- In Côte d'Ivoire, the regression of model 2 by the PMG method is not acceptable. In Côte d'Ivoire, the regression of model 2 by the PMG method is not acceptable. On the other hand, the regression by the MG method is acceptable (ECT = - 0.8459331, p = 0.000) and only electricity consumption has a significant negative impact on access to electricity in this regression (coefficient = - 9.527415 p = 0.041) ;

- In Mali, the PMG regression is not acceptable, but the MG regression is acceptable (ECT = -0.7111549, p = (0.042) and there are no significant variables;

- For Niger, the PMG regression is acceptable (ECT = -0.3971528, p = 0.006). The investment rate is significant (p = 0.042 < 0.05) with a negative coefficient (-0.1444286). In principle, the rate of investment should be able to increase the rate of access to electricity but how can we explain the fact that more investment reduces access to electricity? This inverse relationship can be explained by the fact that most investment is directed towards other sectors of activity that are not really related to the electricity sector;

- The case of Senegal shows that the PMG and MG regressions are not acceptable, but in the case of the PMG regression, the political stability index has a significant negative impact on the electricity access rate (POLISTAB coefficient = -15.07196, p = 0.000);

- In Togo, the MG regression is acceptable (ECT = -0.6939089, p = 0.019), but none of the coefficients is significant.

The following table gives the results of the Granger and Hausman tests:

Table 13. Granger causality test and Hausman test

	Granger causality test
	Coefficients
PIBGROWTH cause AELEC	0.1386517 (0.001)*
AELEC cause PIBGROWTH	0.0082588 (0.894)
Log_CELEC cause AELEC	-0.0042076 (0.454)
AELEC cause log_CELEC	-2.711262 (0.270)
TAUINVEST cause AELEC	0.1230115 (0.035)*
AELEC cause TAUINVEST	0.1579336 (0.374)
POLISTAB cause AELEC	-0.0010844 (0.820)
AELEC cause POLISTAB	-0.5643974 (0.712)

Hausman test (H_0 : difference in coefficients not systematic)		
	Modèle 1	Modèle 2
	Chi 2 (1) = 0.58	Chi2 (4) = 3.25
p-value	0.4451	0.5173
Decision	H_0 not rejected	H_0 not rejected
Which method is good ?	PMG	PMG

Source : Author

The results of the Granger test show that the first hypothesis is verified, i.e. that the causality is unidirectional between the growth rate and access to electricity. The economic growth rate has a positive long-term impact on the rate of access to electricity (p = 0.001). The second hypothesis, which assumes the existence of a bidirectional relationship between electricity consumption and the rate of access to electricity, is not verified. The third hypothesis assuming the existence of a unidirectional relationship between the investment rate and access to electricity is verified. The rate of investment positively influences the rate of access to electricity. The fourth and final hypothesis is not verified. There is no unidirectional relationship between political stability and the rate of access to electricity. Furthermore, the result of the Hausman test allows us to retain the PMG regression as the best estimation method.

4. Conclusion

Finally, the Kao and Westerlund cointegration tests show that the rate of access to electricity is cointegrated with each of the following variables: the economic growth rate, the electricity consumption, the political stability index and the investment rate and that there is a strong interdependence between the WAEMU states following external exogenous shocks. The Hausman test suggests the PMG method for the estimation of our staggered lag autoregressive model (ARDL) with a panel for models 1 and 2. The application of this method shows that in the long run the economic growth rate has a significant and positive impact on the rate of access to electricity for model 1. As for the Granger test, it shows that it is the economic growth rate and the investment rate that cause the rate of access to electricity.

The estimation of model 2 shows that in the long run, the economic growth rate, the electricity consumption and the investment rate have a positive impact on the rate of access to electricity. However, the political stability index is inversely related to the rate of access to electricity. In the long run, for this model, only the positive impact of electricity consumption is significant. In the short run, the PMG regression of model 2 shows that the economic growth rate has a positive and significant impact on the rate of access to electricity in Benin. Also the rate of investment has a negative and significant impact on access to electricity in Niger. It is important to note that this inverse relationship between the rate of investment and access to electricity observed in the short term in all countries can be justified by the fact that the investments made are mainly in other sectors of activity that are not really related to the electricity sector. One could speak of a certain neglect of the electricity sector in terms of grid extension investments. The more other sectors benefit from investment, the lower the rate of access to electricity. In the ratio that defines the rate of access to electricity, the denominator that represents the total population is increasing faster than the population of electrified localities due to the lack of investment in the extension of the electricity network. To change this trend, it is desirable that WAEMU countries, together or individually, make more investments to extend their electricity network. Furthermore, they should implement policies that allow for a better distribution of national wealth in order to increase the GDP per capita of the populations so that they can bear the costs of electricity subscriptions.

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APPENDIX: Data for calculating covariances and correlation coefficients

Table 1. Growth rates and access rates in 9 developed countries for the year 2019.

Countries	France	Belgim	Canada	Germany	Russia	Suisse	Swiss	United Kingdom	Denmark
Growth rates in (%)	1,84	2,15	1,88	1,06	2,03	1,21	1,99	1,67	2,11
Access rates in (%)	100	100	100	100	100	100	100	100	100

Source : World development indicators 2022

Table 2. Growth and access rates in WAEMU countries for 2019

Countries	Côte d'Ivoire	Niger	Senegal	Mali	Burkina Faso	Guinea-Bissau	Benin	Togo
Growth rates in (%)	6,23	5,94	4,40	4,76	5,69	4,5	6,87	5,46
Access rates in (%)	68,55	18,77	70,4	48,02	18,38	31,04	40,32	52,44

Source : World development indicators 2022

Table 3. Growth and access rates in Côte d'Ivoire for 9 consecutive years

Years	2011	2012	2013	2014	2015	2016	2017	2018	2019
Growth rates	-5,37	7,62	10,76	9,37	7,19	7,18	7,36	6,89	6,23
Access rates	55,8	55,8	61,33	61,9	62,6	64,3	65,6	67,2	68,55

Source : World development indicators 2022

Table 4. GBP rate and electrcity access in France for 9 consecutives years

Years	2011	2012	2013	2014	2015	2016	2017	2018	2019
Growth rate	2,19	0,31	0,58	0,96	1,11	1,10	2,29	1,87	1,84
Access rate	100	100	100	100	100	100	100	100	100

Source : World development indicators 2022

Table 5. Values of covariances and correlation coefficients

	Covariance	**Correlation coefficient**
Table 1 (developed countries)	00	00
Table 2 (WAEMU countries)	-2,81	-0,18
Table3 (Côte d'Ivoire)	7,73	0,42
Table 4 (France)	00	00

Source : Author