Energy Growth Nexus: Evidence from Seven West African countries

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RAGATOA, Dissirama Bagnaguim

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Abstract

ENERGY GROWTH NEXUS: Evidence from Seven West African Countries

By

RAGATOA Dissirama Bagnaguim

Mainstream economics doesn't give much importance to energy but, there is no doubt about the contribution of energy to economic activities. This paper looks at the causal effect of electricity on economic in the energy growth nexus in West Africa. We use ARDL bounds test to test for cointegration and Granger causality to identify the causality direction and finally an instrumental variable regression to estimate the causal effect of electricity on economic growth. The ARDL bounds test shows no cointegration between electricity use and economic growth. The Granger causality based on Vector Autoregression model shows a unidirectional relationship from electricity to GDP in Benin and from GDP to electricity use in Ghana and Senegal. However the test shows bidirectional causality in Togo and Nigeria. The causal effect based on instrumental variable approach shows that a 1% in electricity use per capita yields 0.17% increase in per capita income.

Key words: Energy, Economic growth, causality, relationship, Energy policy

주류 경제학은 에너지를 크게 중요시하지 않지만, 경제 활동에 에너지가 기여하는 바에 대해서는 의심의 여지가 없다. 이 논문은 서아프리카의 에너지 성장 넥서스에서 전기가 경제에 미치는 인과관계를 살펴본다. 우리는 ARDL Bounds Test 를 이용하여 공적분 관계를, 그레인저 인과관계를 이용하여 인과관계의 방향성을 시험하고 마지막으로 도구변수 회귀분석을 사용하여 경제 성장에 대한 전기의 인과적 영향을 추정한다. ARDL Bounds Test 분석 결과. 전기사용과 경제 성장 사이에 공적분 관계가 성립하지 않는 것으로 나타났다. 벡터자기회귀모형에 기초한 그레인저 인과관계는. 베냉의 경우에는 전기에서 GDP 에 이르는 단방향적 관계를, 가나와 세네갈의 경우에는 GDP 에서 전기 사용에 이르는 단방향적 관계를 보여준다.그러나 토고와 나이지리아의 경우에서는 양방향의 인과관계를 보여준다. 도구변수 추정법에 근거한 인과관계는 1 인당 전기 사용량이 1% 증가할 경우 1 인당 국민소득이 0.17% 증가한다는 것을 보여준다.

핵심어: 에너지, 경제 성장, 인과 간게, 관계, 에너지전챙

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1. Introduction

One of the most discussed topics in economics is the drivers of economic growth. Economists have tried to pin down growth determinants and some have asked the question to know whether energy consumption causes growth. *Africa Energy Outlook* stated that "In the last five years, nearly 30% of world oil and gas discoveries were made in sub-Saharan Africa" (2014, p.14). It is important to know that "Africa's energy sector is vital to its future development and yet remains one of the most poorly understood regions within the global energy system" (*Africa Energy Outlook*, 2014, p.20). The African continent is full of energy resources, but still is unable to harness that potential to boost economic activities. Energy poverty and energy security are critical issues because modern economies cannot subsist and develop without sufficient energy supply. Energy poverty curtails economic development in both industrial and service sectors. Productivity, especially in the industrial sector, is low due to energy insecurity and power shortages. According to the Energy Access Outlook (2017), health facilities that do not have issues with access to electricity represent only 40%, and according to the United Nations Environment Program (UNEP, 2017), the projected African electricity demand in energy in 2020 will be 1000Twh after a record of 605Twh (363Twh or 60% for Sub Saharan Africa) in 2012. With this relatively high level of demand in 2012, the total final consumption and production in the continent could only reach 247160 ktoe (2.87 Twh) and 764184 ktoe (8.88 Twh,) respectively in 2015 and according to AfDB (2018) the total installed electricity capacity in 2017 was 175Gwh or 0.17Twh. These statistics show the huge gap between the demand and supply of energy in the continent and the necessity of reliable and secure energy supply. The low consumption of energy simply reflects the limitation of production capacity. According to the same document, citing WHO/World Bank (2015, p.49), "an average of only 34 per cent of hospitals and 28 per cent of health facilities in sub-Saharan Africa have reliable electricity access". It also stated, citing AfDB (2014a, p.49), that "about 58% of health care facilities in Sub Saharan African countries have no electricity at all". Meanwhile, in education, in sub Saharan Africa, primary schools that lack electricity or any form of energy services absorb 90% of children. We do believe that those statistics changed over time but not very much. According to the 2016 statistics of the International Energy Agency (IEA), the Total Primary Energy Supply (TPES) in the U.S was 2.65 times bigger than the TPES in the whole continent of Africa.

Meanwhile, the population of Africa was 3.75 times larger than the population of the U.S. The OPEC Fund for International Development (OFID, 2010) citing the World Bank (1999) describes the vicious circle of energy poverty in three steps. First, the lack of energy to operate machines, results in low productivity, poor quality and meager quantity of output per unit of time. The issue is compounded by a reduction in rural women's time related to their duty to collect woods for cooking. That time could have been used for economic activities. Second, that situation leads to a low productivity and little cash. Third, the second stage of little cash restrains the capacity to buy better energy supplies or energy transformation equipment (OFID, 2010).

Considerable research has been carried out on the direction of causality between energy consumption and economic growth since Kraft and Kraft's paper in 1978 (Wolde-Rufael, 2004; Ozturk, Aslan & Kalyoncu, 2010) and among energy, agricultural growth and export (Raeeni, Hosseini & Moghaddasi, 2019). While some people decide to closely look at total energy consumption, some tend to be more specific by looking at the association between electricity use and economic growth (Shiu & Lam, 2004; Seung-Hoon, 2005; Mozumder & Marathe, 2007; Akinlo, 2008). Despite the pieces of research that have been carried out on the topic, the results are mixed and do not allow any generalization.

In recent years, the literature on African countries and particularly West African countries is increasing but research focus on the traditional question of the direction of causality between energy consumption and growth (Odhiambo, 2009; Ouedraogo, 2013). As a result, almost nothing has been done on the real impact of energy consumption on growth. We find the traditional question of the direction of causality interesting since there is not much on this topic in West African countries. Nevertheless, we argue that the question of the real impact of energy on growth is equally or even more important. Energy has played an important role in the development of nations (Smil, 2017), yet people seem to undermine that research area in energy economics. Focusing on the large literature on energy market liberalization, energy consumption and environment nexus (Newbery, 2005; Shin & Managi, 2017), causal direction between energy and growth, previous studies have paid little attention to the important question of the causal effect of energy on economic growth.

In this research paper we propose to investigate the causal relationship between energy consumption and economic growth and the magnitude of the impact of the former on the latter one. Then we will propose few recommendations to promote higher investment in the sector of energy and thus increase production in different sectors of the economy. This research will attempt to answer the following research questions: Is the relationship between energy consumption and economic growth a simple correlation or a causal relationship? If there is a causal relationship then what is the direction of the causality? Does energy consumption affect growth? If yes, what is the magnitude of the impact?

This paper is divided into three sections. First, we will estimate the magnitude of the impact of energy on economic growth. Second, we will identify the direction of the relationship between energy consumption and economic growth in each of the seven West African countries we are working on. Last, we will recommend few policies to promote investment in the energy sector to reduce energy insecurity and energy poverty issues that curtail economic growth.

2. Literature Review

2.1. Energy economics

Before talking about the literature in energy economics, it is important to clarify the key word in the field: energy. In energy economics and energy journals, researchers generally do not define energy but take it as a given. But in this study we decide to consider the definition of Sweeney (2001, p.2), according to whom "in economic terminology, energy includes all energy commodities and energy resources, commodities or resources that embody significant amounts of physical energy and thus offer the ability to perform work". So in this study we are going to consider energy as resources that offer the capacity to work. But it is important to say that this does not include human energy, though human energy also offers the ability to work.

Electricity growth nexus related studies can be divided into two categories. The first one is the one of energy economics and the second one is that of electricity infrastructure investment. While the first one only focuses on causality direction between electricity and growth, the second one focuses on the causal impact of investment in electricity infrastructure. The second one is like a Randomized Controlled Trial kind experiment and is limited by the tendency of researchers to estimate only the short term effect of the intervention. However, electricity infrastructure investment is the kind of investment that takes time to bear fruits (Agence Française de Development (AFD) & World Bank, 2019).

In energy economics, the field in which we place this study, it is commonly recognized that Kraft and Kraft's (1978) seminal paper on the association between energy and GNP in the US was a starting point for studies on the correlation between energy and economic growth. This influential paper has shown that the causal relationship between energy and growth runs from GNP to energy use. Since then, there has been a growing body of literature on the topic. The literature to date shows diverse conclusion that cannot be generalized. The mixed findings on the topic might reflect the difference in the econometric methods used and the variation in the combination of variables and also the difference in sample size (Chien-Chiang, 2006).

2.2. Causality in Energy economics

According to Ozturk (2010), four different types of causality directions exist between energy utilization and economic growth. Each of them is significant in terms of policy recommendation. The first group of research has shown that the causality between energy use and economic growth could be non-existent, referring to the *"neutrality hypothesis"*. This means that there is no causality between the two variables. The second group of research has shown that economic growth causes energy utilization to increase. This refers to the *"conservation hypothesis"* that advocates that as a policy, maintaining stable the energy use level is likely to have no adverse impact on economic growth. The third group of research sustains that energy utilization is the causal factor of economic growth. This is called the *"growth hypothesis"*. It claims that limiting the amount of energy used might harmfully affect growth whereas an increase in energy is likely to contribute to economic development endeavors. Finally, there could be a simultaneous causality: the *"feedback hypothesis"*. Akinlo (2008), using data from eleven countries in Sub-Saharan Africa, found unidirectional and bi-directional relationship for different countries. In many countries, researchers confirmed through their studies the growth hypothesis. This is, for instance, the case of Shiu and Lam (2004) who conducted a study in China and found that electricity use leads to an increase in real Gross Domestic Product. Likewise, Tang, Tan & Ozturk (2016) investigated on the topic in Vietnam. The results of their study show that energy utilization affects economic growth in a positive way. In the same vain, Lee & Chang (2008) also researched on similar topic in 16 Asian countries and found that the short-run causality between economic growth and energy use is non-existant. Nevertheless, there is long-run unidirectional causality going from energy consumption to economic growth. It is worth noticing that in most cases, researchers do not find the neutrality hypothesis to be true, showing that energy is very likely related to economic growth.

An important part of the literature uses Granger causality method to pinpoint causality direction. Since the whole literature focuses on causality, doing a brief summary of the literature without talking about Granger causality would be an incomplete summary. Payne claims that “a time series X is said to Granger-cause another time series Y if the prediction error of current Y decreases by using past values of X in addition to past values of Y” (Payne, 2010, p.2). However, this is not possible if the time series is non-stationary. Therefore, a unit root test is necessary to check whether the variables are stationary without or after differentiation. Some studies use Autoregressive Distributed Lags (ARDL) bounds test of cointegration to check the existence of short-run and long-run dynamics, coupled with Granger causality to identify causality direction (Narayan, 2005; Akinlo, 2008; Odhiambo, 2009).

2.3. Energy growth nexus in Africa

The scholarship on energy utilization and economic development diversified over time to reach other related topics like energy, agricultural growth and export (Raeeni, Hosseini & Moghaddasi, 2019), energy, carbon emission and economic growth (Xing-ping & Xiao-Mei, 2009). While some researchers decide to closely look at the total energy consumption, some tend to be more specific by looking at the correlation between electricity and economic growth (Shiu & Lam, 2004; Seung-Hoon, 2005; Mozumder & Marathe, 2007; Akinlo, 2008).

The extant scholarship on energy growth nexus in Africa is in smaller number compared to other continents like Europe or America. However, there has been a growing interest of academics in the area. Ouedraogo (2010) examined the causality direction between electricity consumption and economic growth in Burkina Faso considering the period 1963 to 2003 using ARDL bounds test and Granger causality. The study finds in the long run a bi-directional relationship between electricity use and GDP growth and between capital formation and GDP. In 2013, Ouedraogo investigated on the relationship between energy use, energy prices and growth and also electricity use, prices and economic development for the period 1980 to 2008. She focused on the Economic Community of West African States (ECOWAS) and used panel unitroot test, panel cointegration test and panel Granger causality. The study revealed that there is unidirectional causality going from GDP to energy use in the short run and energy use and electricity use to GDP in the long run. Odhiambo (2010) analyzed the correlation between energy use and GDP growth in South Africa, Kenya and Democratic Republic of Congo (DRC) using Panel data and ARDL bounds test procedure. In South Africa and Kenya, the results confirm the growth hypothesis. However, in DRC, the conservation hypothesis was found to be true. Likewise, Wolde-Rufael (2004) analyzed the relationship between electricity use per capita and GDP per capita in 17 countries in Africa for the period 1971-2001. The author used ARDL bounds test and a modified version of ganger causality. He found that in six countries GDP per capita growth Granger-causes electricity use per capita growth, in three countries the opposite direction is true and in three other countries there is a bi-directional causality. In 2005, using a panel data over the period 1971-2001, Wolde-Rufael also investigated the relationship between per capita energy utilization and per capita GDP for nineteen African countries. The results show a simple correlation between the two variables for eight countries and causality for ten countries. Akinlo (2008) using ARDL bounds test with Granger causality test based on a Vector Error Correction Model (VECM) identified the causality in eleven Sub Sahara African countries. The results showed unidirectional causality from economic growth to energy use in 2 countries, bidirectional causality for 3 countries and no causality at all for three other countries.

In this research paper, we do not aim to determine the relationship between energy use and economic growth in the West African region. Instead, we will first try to identify the correlation between per capita electricity use and per capita income in only seven countries in West Africa, namely Cote d'Ivoire, Togo, Niger, Benin, Senegal, Ghana and Nigeria. This is due to the availability of relevant data in those countries. Secondly, we will attempt to estimate the causal impact of electricity consumption per capita on GDP per capita PPP. We do know that electricity represents only an insignificant part of total energy utilization in those countries, 4% of Total Final Consumption in Sub-Saharan Africa if we do not count South Africa (UNEP, 2017). Yet, we decided to work on electricity instead of bio-fuel or total amount of energy consumption because electricity is more correlated with GDP inasmuch as it is more widely used in a range of energy services whereas bio-fuel is more used in energy services that reflect a limited growth, namely space heating and basic material industries (Kornelis, 2007).

3. Data and Methodology

3.1. Data

We intend to conduct this research by using data from the World Bank website, the Penn World Table and Variety of Democraties (V-Dem) databank for the period 1969-2017 and analyze them using econometric methods to identify the causal relationship and the magnitude of the impact of energy on economic growth.

GDP per capita PPP is my dependent variable. I used GDP per capita PPP to identify the real impact of energy on the real purchasing power of people. And I used constant 2011 to facilitate a comparison over time of the purchasing power by using fixed prices of 2011. We use annual electricity use per capita measured as kg of oil equivalent as my variable of interest. We decide to use electricity instead of TPES because electricity has more productive uses than other forms of energy. As control variables we used labor force participation rate (% of total population aged 15+, modeled ILO estimate), gross fixed capital formation current 2010 $US. We included labor and capital inasmuch as they are used by many other researchers in energy economics and have always been part of the classical production function. We also added trade as % of GDP, FDI (foreign direct investment net inflow % of GDP). I chose Trade and FDI because they are also important in the global economy of a country, especially FDI in the case of sub-Sahara African countries. All the above listed variables are from World Bank. We also used as control variable human capital from the Penn World table and public sector corruption to represent the state of institutions. This last variable is from Variety of Democracies.

Table1: Descriptive statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
Log Electricity use per capita	279	4.649267	0.7402779	2.374964	6.054295
Log Crude Oil Price	343	3.06922	1.085281	0.1906204	4.695468
Human capital	322	1.373069	0.3126299	1.009448	2.374476
Log capital	324	25.34504	3.490389	9.903487	30.50909
Log labor	196	4.196028	0.1693372	3.833542	4.397826

Log FDI	290	1107721	1.324924	-6.950336	2.934802
Log Trade	308	3.99717	0.466639	1.843774	4.947768
Public sector corruption	343	0.6732682	0.1540892	0.205	0.93

3.2. Methodology

The causal relationship in this study will be identified in three steps: First, we will use the Autoregressive Distributed Lag (ARDL) bounds test of cointegration to know whether there is a long-run relationship between variables. Cointegration methods generally require the variables of study to have the same order of integration but one of the advantages of ARDL bounds test is that it has no such requirement. Thus, there is no necessity to use a unitroot test beforehand. Nevertheless, none of the variables should have a second level integration (Pesaran, Shin & Smith, 2001). Another advantage is that the sample size does not affect the results of the test and "the ARDL technique generally provides unbiased estimates of the long-run model and valid t-statistics even when some of the regressors are endogenous", according to Odhiambo (2009, p.3). Second, based on the results of the ARDL test of cointegration we will specify a Vector Autoregressive (VAR) model in case of a short run relationship or a Vector Error Correction Model (VECM) in case of a long run relationship between electricity and GDP to capture the short run or/and the long run dynamics. Third, we will use a Granger causality test to identify the causality direction between electricity consumption and economic growth. We will estimate the magnitude of the impact of electricity use on economic growth by using an instrumental variable regression approach to solve the eventual reverse causality issue, which in energy economics is reflected into the feedback hypothesis. This hypothesis states that there is a bi-directional causality between energy consumption and economic growth. In other words, energy consumption causes economic growth and concomitantly economic growth causes energy consumption. In order to show that our instrumental variable approach is relevant, instead of simply assuming a reverse causality, we use the Granger causality test to test whether the feedback hypothesis is true or whether there is reverse causality in our dataset.

For the ARDL bounds test we specify a bivariate model to identify the cointegration relationship between electricity use and income. We test the null hypothesis H_0: $lIncCP_{it} = 1lEc = 0$ and the alternative hypothesis is H_1: $lIncCP_{it} = 1lEc \# 0$ and reject the null hypothesis if the F-statistics is greater than the critical value. The model specified for this is:

$$\Delta lIncCP_t = \alpha 0 + \sum^{n}_{j=i} \beta_1 \Delta lIncCP_{t-i} + \sum^{n}_{j=i} \beta_2 \Delta 1lEc_{t-i} + \gamma_1\, lIncCP_{t-1} + \gamma_2 1lEc_{t-1} + \varepsilon_t$$

Where Δ represents the first differencing term and ε is the error term. All variables with the first differencing sign (Δ) capture the short run relationship between electricity use and income, while the same variables without the Δ sign captures the long run dynamics between our two variables.

We specified four different models to capture the relationship between and causal effect of electricity use per capita on income per capita PPP. The most elementary model specification would be the one that identifies GDP per capita PPP as solely depending on electricity use per capita and the error term:

$$lIncCP_{it} = \alpha_0 + \gamma 1lEc_{it} + \varepsilon_{it.}$$

This model is obviously a very naïve model but we decide to use it as the basic baseline comparison model. The second model is an augmented version of the previous one where we control for some observable variables that are likely to affect our estimate such as human capital, gross fixed capital, labor, FDI, trade and corruption in the public sector. These controls are abundantly used in the literature as controls for income:

$$lIncCP_{it} = \alpha_0 + \gamma 1lEc_{it} + \gamma 2hc_{it} + \gamma 3lcapcu_{it} + \gamma 4labor_{it} + \gamma 5lFDI_{it} + \gamma 6lTr_{it} + \gamma 7Psc_{it} + \varepsilon_{it}$$

For the previous two models we used a pooled OLS regression without and with controls.

The third model uses a panel fixed effect approach where we control for country fixed effect and time fixed effect in addition to the controls added in the second model. Without these fixed effects our regression would yield biased estimates inasmuch as we have in our data different countries with different socio-economic realities that incurred over the years different shocks. The fixed effect allows us, therefore, to control for the variables that are differences across countries but static over time and that are static across country but changing over the years:

$$lIncCP_{it} = \alpha_0 + \gamma 1lEc_{it} + \gamma 2hc_{it} + \gamma 3lcapcu_{it} + \gamma 4labor_{it} + \gamma 5lFDI_{it} + \gamma 6lTr_{it} + \gamma 7Psc_{it} + \lambda_i + \lambda_t + \varepsilon_{it}$$

The fourth and last model presents an Instrumental Variable approach to solve the eventual reverse causality issue between electricity use and income. The conservation hypothesis, as developed in energy economics, tells us that as GDP increases, energy (electricity) consumption also increases. Therefore if electricity consumption also can lead to an increase in GDP, we expect the effect of GDP on electricity to create an upward bias on the effect of electricity on GDP, creating a simultaneous causality bias. So in order to make sure that our estimate does not take into account the initial push of GDP on electricity use, we decide to use an instrumental variable to make the variable electricity use per capita exogenous. We use the instrumental variable with only a country fixed effect.

The instrumental variable we decide to use is the OPEC oil price. The first condition for an instrumental variable regression is relevance of the instrumental variable, that is corr (Z,X) # 0. We argue that the first condition is met since the underidentification test that test the null hypothesis Ho: corr (z, x) = 0 is rejected with a 0.000 p-value and the test of weak identification test that test the null hypothesis weakly identified equation is rejected with a F-statistics above 20. The second condition for an IV approach is exogeneity of the excluded instrumental variables. That condition is strictly speaking non testable and we could not run the the overidentification test since we only have one excluded IV in the regression equation. We can also argue that our IV does not appear in the main regression equation. Even if energy appear in some production function as a production factor like in the case of labor, capital and land the price of energy itself does not appear in production functions. Besides, though the exogeneity of our instrumental variable (OPEC oil price) is not testable, we can argue that OPEC oil price is an international oil price that is decided outside and regardless of our economies at study but that affects pretty much those economies. Therefore the OPEC oil price is not affected by the seven economies at study (Y does not impact Z. Even if we agree that the increase in GDP increases the use of electricity, we cannot argue that increase in electricity use in our seven economies impacts the international OPEC oil price $Y \longrightarrow X \not\longrightarrow Z$) but those economies are effected by the international OPEC oil price through the variation the change in price creates in the electricity use in those countries (Z impact Y through X).

1st stage

$$lEc_{it} = \alpha_0 + \beta 1lCrp_{it} + \beta 2hc_{it} + \beta 3lcapcu_{it} + \beta 4labor_{it} + \beta 5lFDI_{it} + \beta 6lTr_{it} + \beta 7Psc_{it} + \lambda_i + \varepsilon_{it}$$

2nd stage

$$lIncCP_{it} = \alpha_0 + \gamma 1lEc_{it} + \gamma 2hc_{it} + \gamma 3lcapcu_{it} + \gamma 4labor_{it} + \gamma 5lFDI_{it} + \gamma 6lTr_{it} + \gamma 7Psc_{it} + \lambda_I + \varepsilon_{it}$$

Where:

lEc is log of electricity use per capita; lIncCP is log of GDP per capita PPP; lcapcu is log of fixed capital formation current; lCpr is log of OPEC crude Oil Price; lTr is log of Trade as a percentage of GDP ; labor is log of labor force participation 15+ (% of total); lFDI is log of FDI net inflows (% of GDP); Psc is public sector corruption; λ_i is a country dummy and λ_t is time dummy.

i = individual country

t = year of observation

4. Results and Discussion

4.1. The ARDL bounds test of cointegration

Our approach is to identify the causality direction between electricity use and GDP using the Granger non-causality test for each country except Niger[1]. If in at least one country we find a bidirectional relationship between the two variables or if at least in one country the feedback hypothesis is true, that would mean that there is reverse causality between electricity use and GDP in our data and that would help us decide the best identification strategy.

We consider this approach to be an alternative to the panel Granger causality developed by Dumitrescu and Hurlin (2012) that tests the null hypothesis of Granger noncausality against the alternative hypothesis of Granger causality from the independent variable to the dependent variable in heterogeneous panels in at least one of the panels. What we consider to be a

[1] Niger does not have enough electricity data to produce conclusive, significant and trust worthy cointegration and causality results so we decide to not run cointegration and Granger causality analysis for Niger. But still as long as one of the remaining 6 countries show a bidirectional causality direction, our approach holds.

shortcoming of this test is that in case of rejection of the null hypothesis, it does not provide information on the precise panel where there is Granger causality from X to Y. But by running the analysis for each country, we can easily pin down the panels where there is Granger causality.

Table 2: ARDL bounds test results

Country	Null Hypothesis : No Cointegration (F-Stats)	
Togo	1.180	
Benin	2.275	
Cote d'Ivoire	0.325	
Ghana	3.835	
Nigeria	0.139	
Senegal	2.476	
Critical Values	**Lower Bound**	**Upper Bound**
10%	4.379	5.494
5%	5.749	7.115
1%	9.504	11.520

Critical values from Kripfganz and Schneider (2018)

Table2: shows the ARDL bounds test results. We specify a bivariate model for the bounds test because of multicollinearity issue that occurs as we try to include additional variables. The null hypothesis of no cointegration is rejected only if the F-statistics is above *Kripfganz and Schneider's (2018)* upper bound critical value and it is rejected if the F-statistics falls below the lower bound critical value. The authors' critical values are a better version of Pesaran et. al's (2001) critical values and those of Narayan (2005). The critical values are given based on the number of independent variables, observations and short-run coefficients. Kripfganz and Schneider (2018) propose to increase the number of lags in case of doubt about remaining serial error correlation although the bounds test has a serial uncorrelated, homoscedastic and normally distributed error terms. Therefore we decided to use an optimal lag order specific to each country data. Based on the results in the table, we cannot reject the null hypothesis of no cointegration in any of our countries. This means there is no long run relationship between electricity use and GDP in Togo, Benin, Cote d'Ivoire, Ghana, Nigeria and Senegal even at 10% level of

significance. Our cointegration results are same as those found by Akinlo (2008) except for Cote d'Ivoire, Senegal and Ghana[2]. Though, the authors used a different sample size and a multivariate model. We then use a vector autoregressive model since we failed to reject the null hypothesis of no cointegration and test the null hypothesis of Granger noncausality.

4.2. Granger causality

Table 3: Granger causality wald test results based on Vector autoregressive model (VAR)

Country	Electricity → GDP	GDP→ Electricity
	Short-Run	Short-Run
Togo	24.981***	7.714***
Benin	7.754***	0.009
Cote d'Ivoire	20.661***	2.072
Ghana	0.081	4.113**
Nigeria	18.959***	2.742*
Senegal	15.811***	1.478

The results of the Granger causality shows that there is a unidirectional causality running from electricity to GDP in Benin, Cote d'Ivoire and Senegal supporting the growth hypothesis in those countries. The results also reveal a unidirectional causality running from GDP to electricity use in Ghana, supporting the conservation hypothesis. This result is also found by Wolde-Rufael (2006). But more importantly we find a bidirectional causality running from to electricity use to GDP and GDP to electricity in Togo and Nigeria. This finding supports the feedback hypothesis and also means that there a reverse causality in our data. The methodological implication of this result is that since we found statistical evidence of a simultaneous causality between electricity and GDP in not one but two countries, we can conclude that an instrumental variable approach would be the best identification strategy.

[2] In Ghana the authors found an inconclusive result as the F-stats fell between the lower and upper bounds of the critical values.

4.3. Electricity growth nexus

Table 4: Relationship between income per capita ppp and electricity use per capita

	(Pooled OLS)	(Pooled OLS with controls)	(Panel Fixed Effect)	(IV First Stage)	(IV Second Stage)
VARIABLES	Log income per capita ppp	Log income per capita ppp	Log income per capita ppp	Log Electricity	Log income per capita ppp
Log Crude Oil Price	---	---	---	0.19*** (0.04)	---
Log Electricity per capita	0.45*** (0.04)	0.32*** (0.08)	0.12* (0.06)	---	0.17** (0.09)
Human capital	---	0.43*** (0.11)	0.78*** (0.22)	1.27*** (0.24)	0.06 (0.20)
Log capital	---	0.03*** (0.01)	0.13*** (0.02)	-0.11*** (0.03)	0.12*** (0.01)
Log labor	---	-1.67*** (0.22)	1.08 (0.82)	0.86 (0.71)	1.91*** (0.34)
Log FDI	---	-0.04** (0.02)	-0.00 (0.01)	0.02 (0.02)	-0.01 (0.01)
Log Trade	---	-0.22*** (0.07)	-0.13** (0.06)	-0.05 (0.09)	-0.22*** (0.04)
Public Sector Corruption	---	0.75*** (0.14)	0.01 (0.15)	0.05 (0.20)	-0.25*** (0.07)
Country Fixed Effect	No	No	Yes	Yes	Yes
Time Fixed Effect	No	No	Yes	No	No
Constant	5.49*** (0.21)	11.88*** (1.15)	-1.84 (3.65)	1.49 (3.25)	-4.15** (1.65)
Observations	165	154	154	154	154
R-squared	0.35	0.85	0.99	0.95	0.98

Robust standard errors in parentheses
***, ** and * denote 1%, 5% and 10% significance level.

4.4. Interpretation

Table 2 presents the results of our empirical strategy. We present the results of simple pooled OLS without controls, with controls, fixed effect and Instrumental Variable regressions with robust standard errors.

We consider our pooled OLS with no control as a baseline comparison model to track the change in coefficients as we change our regression method. The pooled OLS estimates show that a one percent increase in electricity use per capita yields a 0.45% increase in income per capita ppp and is significant at 1%. This estimate is extremely big and could definitely not be true even in developing countries. We assume that in developing countries that have a serious problem of energy poverty, the increase in income due to increase in electricity use per capita would be higher compared to developed countries particularly because of the tremendous gap between demand and supply. For instance, according to Blimpo and Cosgrove-Davies (2019, p.26) in 1920s, electricity accounted for almost "half of the total factor productivity growth" in the United States' manufacturing sector. Nevertheless, this estimate is very likely unrealistic.

In the second column we provide the results of multiple regression analysis controlling for human capital, gross fixed capital, labor, FDI, trade and public sector corruption. The results indicate a decrease in the coefficient of interest as we expected, showing an overestimation in the first column results, stemming from the effect of other variables correlated with income.

Our third column points out the fact that when we control for time invariants that are different across countries and state invariants that change over time with other controls, the coefficient of interest drops significantly from 0.32 to 0.12 and suggest that 1% increase in electricity consumption per capita leads to 0.12% increase in per capita income ppp. This means that there are unobserved characteristics that seriously inflate the effect of electricity use per capita on per capita income.

The fifth column presents the results of the Instrumental Variable regression. Since we found a simultaneous causality between electricity and income, we expect the effect of GDP on electricity to create an upward bias on the effect of electricity on GDP. Therefore we intuitively expect the computed coefficient of the effect of electricity to be lower than the one in the third column once we correct the bias using the Instrumental Variable method. But the results show that after solving the reverse causality issue, the effect of electricity use per capita on income per capita ppp is bigger. The results suggest that 1% increase in electricity use per capita yields 0.17% increase in per capita income ppp. This could have been caused by the fact that we did not use time fixed effect together with the instrumental variable approach. Thus, in order to check whether the absence of time fixed effect (column 5) is really the cause of that situation we decide to remove the time fixed effect in the panel fixed effect regression approach too (column 3). If the coefficient increases, that would mean that the absence of time fixed effect in the IV regression could explain the counter intuitive results. But here again the results show that after removing the fixed effect in the regression of the third column the coefficient does not increase but decreases. It suggests that the absence of time fixed effect in the fifth column regression cannot explain the counter intuitive results.

The pattern that comes out of the results presented in table 4 is that as we use a better regression method, the coefficient of interest keeps falling (column 1-3), suggesting that the real effect of electricity use is way lower than what we found in the first column and we keep coming closer to it. Even though the statistical evidence provides a counter intuitive result in column 5, there is no big difference between the fixed effect and IV regressions (only 0.05 percentage point of difference). Thus, we believe the real effect of electricity use per capita on income per capita ppp to be somewhere between 0.12 and 0.17 (0.14).

5. Policy Recommendation

5.1. 1990s New Model of Organization of the Electricity Sector

In 1990s, multilateral institutions promoted a new model of organization of the electricity sector. The new model wanted the electricity sector to become more competitive through the introduction of the private sector that would end ineffective monopolies. The energy sector is well known for its natural monopoly. If the electricity sector is subject to natural monopoly then, it is also very likely to be subject to political interference and other inefficiencies such as over-estimation of the demand to satisfy supply obligations, leading to over-capacity investment; lack of cost minimization incentives; abuse of monopoly; adverse effect of huge capital investment on government debt; greater focus on supply-oriented policies (more generation or production capacity) compared to demand side policies that are end user oriented and promote rational use of energy (European Association for the Promotion of Cogeneration, 1997). The 1990s new model of organization of the electricity sector aimed at removing/reducing those inefficiencies by introducing the private sector and competition, regulating and restructuring the electricity sector.

The 1990s electricity sector reform was not a great success everywhere. Some countries could more easily adopt the reforms compared to some others. According to Foster and Anshul (2019) the failure encountered by the new model in some countries was due to many reasons such as:

- The mismatch between the political system and ideological orientation of the countries.
  Reform in the electricity sector generally happens in a broader context of an oil shock or a huge debt of the government-owned electricity company, forcing a reform in the sector. This mismatch leads to delays in the implementation of the reform and also partial implementation. While centralized political systems encountered more failures, free market economies recorded more success. Since local political actors play an important role in the global reform coliseum, the political environment becomes an important factor that influences adoption and implementation of reforms.
- The fact that some countries were not prepared for the wholesale market.
  Only one over five developing countries established a wholesale electricity market. This is because transiting from natural monopoly to wholesale market requires some preconditions. According to Rudnic and Velasquez (2018, p.5) “The introduction of wholesale competition is a relatively complex measure intended to further improve efficiency in a sector that is already functioning relatively well” yet, it requires the financial health of the power industry, a competition amid suppliers that is provided by the generation sector, good governance system and institutions and sound social, political and macroeconomic environment. Many developing countries struggle with these preconditions, therefore are stuck at the intermediate level of single buyer model with its own inefficiencies.
- Difficulties to fully apply adopted regulations.

Many developing countries created regulation agencies. The important question is not only to know whether there is a regulation agency or not but, to know how well the mission and functions of the agency defined, and how well the regulations respected. The dichotomy between well written regulations and their practical implementation is a wide door open for inefficiency. Foster and Anshul (2019) claim that while in 95% of countries the law gives regulation agencies power to fix electricity prices, only in 65% of countries prices are really fixed by those agencies. This situation questions the governance system in place. It seems obvious that if each institution is not granted full power of decision, action and the liberty to express its expertize within the boundaries of its mission and functions, there will be no advancement.

- Difficulties to reach cost recovery objectives.

  Cost recovery is one the important issues in the electricity sector. Tariffs adjustment turned out to be not implementable because likely to be unbearable for end-users. The commonly adopted alternative option was cost reduction for end-users.

The straight forward lesson we learn from the 1990s model proposed by multilateral institutions is that there cannot be a universal policy that can work everywhere and there are many other examples that proved it. The proposed policies were adopted by many developing and developed countries such as Viet Nam, South Korea and South Africa but those countries also had their own specificities, their own policies to tackle their energy issues.

5.2. Country case and suggestions

Table 5. Energy Policy examples

	VIET NAM	SOUTH KOREA	SOUTH AFRICA
	Privatization to cope with capital investment needs	Introduction of market mechanism through privatization and de-monopolization	Electricity Tariffs adjustment via investigation of electricity tariffs structure, its effect on the economy and effect of regional tariffs differentiation
	Reduction of government subsidy to the electricity sector		
	Remedy price inefficiency through price adjustment	Restructuring the energy sector	

			by an independent body
1990s new model's related Energy Policies	Competition among generation and distribution of companies	Substantial management autonomy granted to state-owned enterprises via the Public Enterprise Management Law	Autonomy of the Energy Agency ESCOM
	Improvement of demand side efficiency	Reduce government intervention in Oil pricing (should be market based)	Establishment of an independent regulator of the electricity sector
	Restructuring EVN into 4 transmission companies and power companies	Broader institutional energy reforms	Energy efficiency
	Establishment of an independent regulator of the electricity sector		
	OTHERS POLICIES		
	Frequent audit of generation companies to check their compliance with the code of conduct and profit maximizing objectives	Energy rationalization program aimed at shooting down coal mines to reduce their increasing demand for subsidies	2% of ESCOM's income to subsidize energy intensive users to protect export-oriented energy intensive industries against electricity price hike.
	Power Master Plan	Energy research institutes	Energy Research Center
		Energy Technology Development Plan	Free basic electricity of 50Kwh/month to encourage higher use of electricity
		Power Master Plan	
		Diversification of energy sources	

Source: Assessment of power sector reforms in Viet Nam: Country report.

2012 Modularization of Korea's Development Experience: Energy Policy.

The Origins and Development of South African Energy Policy

Based on the above mentioned failures of the 1990s new model of organization of the electricity sector and the cases of Viet Nam, South Korea and South Africa, we can draw out some recommendations.

It is important for countries to have an energy research center to urge a rigorous collection of reliable energy data and conduct research to inform the government about the impact of energy or electricity use on respective economies, the loss incurred by respective economies due to energy insecurity. According to analysts, the second stage of load shedding in South Africa costs the economy $136 million a day (The Africa report, 2019). This is a significant loss for the economy and there is no doubt that such losses due to load shedding and energy poverty in general curtails development. The energy research center should be at the heart of national energy policies.

The energy research institute can facilitate the outline of a National Power Master Plan that clearly defines in the medium term the development objectives of the energy sector and electricity sub sector and the different strategies to reach the defined objectives. This Master Plan is as important as a National Development Plan, it is important for a better monitoring of activities, successes, failures and the definition of the way forward in the sector. Among our countries of interest, some countries like Ghana and Nigeria have their power master plan but it seems not all francophone countries in the group do have such plan. For countries like Nigeria, a development plan for energy technology could also be of a great help.

For this to happen there is an urgent need to up skill the existing labor force. There is a need for qualified researchers, managers and entrepreneurs to run research centers and electricity companies. Africa Energy Commission (AFREC) of the African Union is an example of praise worthy initiatives to boost the Energy Information System (EIS) in Africa. It not only collects country-specific energy data but it also trains people to accelerate the achievement of their objectives.

The energy market model in most of our countries of interest is the single buyer model. Only in Togo and Benin the market is liberalized. An important question is to ask whether the liberalized markets are efficient and sustainable for those economies, whether those countries respect the pre-conditions for a liberalized market, whether the single buyer model is the best for our developing countries. According to Rudnic and Velasquez (2018) the major disadvantages of the single buyer model are found in developing countries as the model calls on corruption, reduces incentives for payment, impedes competition and diminishes the efficiency of power generation. Although it also has its advantages, to reap those advantages, it requires a low private investment risk, "the efficient use of plant output" (p.15), a competitive and transparent selection of Independent Power Producers etc. Besides, as the authors mentioned, when citing Newbery (2002), a liberalized electricity market does not guarantee that one will avoid risks incurred in the single buyer model.

We can say there is no all safe model. Therefore it is necessary for each country to check the efficiency of its model, different ways to better the model to reduce its disadvantages and check all other possible alternatives.

Another important thing one should draw attention on is regulations. There is a necessity for a better application of regulations. It is important to continuously think about regulations that can allow us to make things move forward but more importantly, countries should work on the real application of those regulations, the reduction of the gap between official regulations and their implementation. For that to happen, regulation agencies should be really independent and have full power to do their job.

Reducing inequality can also be a pro-poor policy to make cost recovery tariffs more bearable for those who are more likely to be affected by the new tariffs. That portion of the population is likely to be not the poorest since in developing countries like our countries of interest, the poorest that are mostly in rural areas do not even have access to electricity (Foster and Anshul, 2019). But still, reducing inequality can not only allow people who cannot afford electricity to afford it but it will also allow people to cope better with tariffs adjustment.

Reducing investment risk is another big deal that has a huge relief potential for many Sub Sahara African countries. Many Sub Sahara African countries suffer from high risks due to global macroeconomic, political and social factors. An important question is to know whether those risks really reflect the reality of those countries whose leaders do not cease to contest the numbers released by international organizations. In any case, it seems urgent for governments to reduce investment risks as it will attract private investors to invest in the capital intensive energy sector, allow governments to reduce their subsidies to the energy sector and thereby slow down the increasing government debt.

Lastly, our recommendation is a detailed case study of the energy market model and structure of each one of our countries of interest for tailored country-specific solutions. General recommendations are okay but, there is a need for an in-depth study of the energy market model and structure of each country to find out their respective failures and successes, merits and short-comings, their respective potential that could allow us to provide better solution approaches; a time consuming but exiting experience that this study cannot cover.

Conclusion

This paper has sought to investigate the relationship between electricity consumption and economic development. It has focused in particular on the causal effect of electricity on income. This paper has drawn attention on the possibility to analyze the causal effect of energy on economic growth in energy economics to identify how important electricity and broadly energy is in different economies.

The findings of this paper build upon the research of Akinlo (2008) and Wolde-Rufael (2006). The paper has highlighted the possibility of going beyond the single causality direction question. Instead of making the causality direction investigation the final step, we decide to use the results of the investigation as a justification for our causal effect analysis approach. The ARDL bounds test could not give any evidence of a long term relationship between electricity use and income, therefore we only specified a VAR model. Besides, the Granger causality analysis gave us evidence of bidirectional causality thus a reverse causality in our data, thereby justifying the instrumental variable regression.

The paper has also underscored different policies in the energy sector. It aimed at broadening the eventual policy recommendations in energy economics, as these results have important implications for energy policies.

Even though our methods and estimates may not be entirely reliable and our sample size not very big, we do believe that kindred studies could cast light on better approaches to capture the magnitude of the impact of electricity and more broadly energy on economic development. Also we acknowledge the fact that one should be careful when interpreting the results of the instrumental variable approach inasmuch as we could not test or strictly prove the exogeneity of our instrument.

Expectantly, this paper spurs more studies on the possible causal effect of energy consumption on economic growth in energy economics. Future investigation might consider country specific approaches using micro data. Further research might consider the effect of energy consumption on not the entire economy but different sectors of the economy like industry, transport, service, employment etc.

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