Determinants of Electricity Demand in Cote D'Ivoire, Ghana, Nigeria and Senegal

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Abstract: It has been established that a consistent supply of electricity to sectors of an economy is vital for economic growth. Countries in West Africa have not realized their full economic potential due to limited access to electricity. The problem with limited energy consumption has been compounded by an unstable supply of power. In this regard, diverse studies have sought to ascertain the factors that influence the consumption of electricity. However, in West Africa, there are very limited empirical works carried out to establish the determinants of electricity consumption and this has necessitated this study. The pooled OLS method is used to examine the determinant consumption of electricity for the period 1980 to 2018. In addition, the study focuses on four countries in West Africa: Nigeria, Ghana, Cote d'Ivoire and Senegal. The results indicate that gross domestic product, foreign direct investment, trade openness, industry output and population growth show a positive and significant relationship with electricity consumption. However, consumer price index has a negative and significant influence on the quantum of electricity consumed. The study recommends that projects focused to increase electricity generation capacity in West Africa should be encouraged and energy from clean sources should be harnessed to provide electricity.

Keywords: electricity consumption; electricity access; economic growth

1. Introduction

Energy is a critical asset that drives economic growth [1]. It constitutes a significant factor for national development [2]. It is undoubtedly an engine of growth to the economies of the world and energy consumption tends to grow alongside gross domestic product (GDP) [3]. Electricity is currently the most used form of modern energy for economic activities. Electricity access plays a very important role in poverty alleviation in developing countries. Available and accessible electricity would give developing countries an opportunity to engage in income-generating activities that will significantly improve their distress.

In addition, electricity has the potential to increase production through various mechanisms when adequately supplied [4,5]. Stable electricity supplies will have a major impact on output quantities [6,7]. Inadequate supply of electricity also means that the manufacturing sector, which relies heavily on electricity, significantly suffers [8]. With the ability to afford generators and plants, industries can increase power supply and function at an elevated cost of production [9,10]. It transcends their production to higher prices, and they are made to compete less compared to their competitors in other global jurisdictions who operate at moderately lower costs due to a reliable power supply.
Moreover, access to reliable electricity can ensure that labor can be substituted for capital that can ultimately increase production. Capital-intensive methods of production have the ability to quickly increase production compared to labor-intensive methods. Adequate supply of electricity would promote the alteration from labor-intensive methods of production to capital-intensive methods of production [11,12].

The energy sector of Africa remains essential to the economic development agenda of the continent. Energy resources, such as solar, wind and hydro, to name only a few, are abundantly available in Africa. Therefore, the energy sector has resources that are sufficient to meet domestic needs if properly harnessed and handled. In North and West Africa, the concentration of oil and gas gives rise to enormous reliance on the use of fossil fuel in electricity generation [13]. However, countries in Eastern and Central Africa are largely dependent on hydropower for electricity generation [14,15]. Electricity is generated in the southern part of Africa using coal and, to some extent, hydropower [16].

Despite Africa’s enormous energy capacity, the consumption of energy as a whole and electricity consumption in particular are very low compared to other continents [17]. For example, the share of the population with access to electricity in a country for example in Liberia it is estimated at approximately 21% compared to 100%, according to data of the 2017 World Development Indicators [18]. In comparison, countries with access to electricity face prices for an inadequate supply with regular power outages. Scheduled blackouts are a frequent occurrence in the area, as are spontaneous power outages [19]. Economic losses in West Africa are estimated at an annual rate of 1 to 5% of GDP [20] due to power interruptions.

Access to electricity is an important topic directly affecting income and inequality [21]. The poor output of the energy grid slowed economic growth between 1990 and 2005; the GDP per capita growth was reduced in Africa as a whole by 0.11% a year and in South Africa by as much as 0.2% [22]. While some African countries’ electrification programs have enhanced access, many other African countries found no significant improvement in electricity supply. In addition, the average electrification rate for sub-Saharan Africa is just 43% [19,20], while Northern Africa is virtually entirely electrified. Furthermore, it is noted that more than 600 million people live without electricity in Africa and even more than 80% of those residing in the rural areas do not have access to electricity [23].

In West African countries, less than 40% of their populations have access to electricity. This is below the globe average rate of 87% [24]. In Ghana, approximately 85% of the entire populace had access to electricity by the year 2018 (World Bank Development Indicators’ (2016)). Countries such as Cote d’Ivoire, Senegal and Nigeria follow with approximately 66%, 62% and 54%, respectively, of their populations having electricity access [25]. As a sampling framework, this study focused on countries that have more than 50% electricity access rate since this will help to better estimate how energy consumption relates to economic growth.

The availability of contemporary, reliable and competitive energy services is widely acknowledged as a necessary and undeniably important instrument for economic development. However, according to [26], population growth coupled with a fast-growing economy in West Africa especially in recent years and particularly in the urban areas means a rapid growth in energy demand. Africa is estimated to have a very youthful and rapidly growing population and [27] reveals that there is strong correlation between population growth and energy demand. As population grows, it is often associated with high acquisition and heavy usage of energy-consuming gadgets and equipment. As a result, population growth has a direct relationship with energy demand, such that as a population grows, it directly leads to a growth in energy demand.

Again, economic growth is argued to equally have a direct relationship with energy consumption [28]. Economic growth is largely driven by modernized agriculture, conversion of goods into finished and semi-finished goods and the provision of services, in which energy is a major input for production. Economic growth and electricity consumption move together in the long run [29]. Basically, it suggests that energy demand and population growth have a bidirectional relationship whereby the more energy is being consumed,
the faster the growth of the economy, all things being equal. It therefore suggests that as developing countries such as the West African countries seek to propel growth, their demand for energy is expected to rise.

The above scenarios raise energy security threat as the population and economic growth projections both indicate the demand for energy would rise and the demand for electricity would surpass the electricity supply in various countries. Access to electricity in most West African countries remain very low; however, cities and urban areas are rapidly growing in population and this is raising energy demand [30]. There are also growing factors in developing countries that contribute to increasing energy demand [31]. It is on this basis that this study seeks to identify the various factors that are increasing the demand for electricity in these West African countries.

A number of diverse studies have investigated the correlation between energy consumption and economic growth [32]. Few studies have, however, tried to determine energy consumption determinants. In addition, work on electricity factors has concentrated on other African countries with a few others concentrating on sub-Saharan Africa. Many researchers have carried out various studies in this regard. To the best of the researchers’ understanding, the determinants of electricity use in West Africa have not been quantitatively evaluated; therefore, the aim of the study is to investigate the determinants of electricity demand in Cote D’ Ivoire, Ghana, Nigeria and Senegal. Section 2 will provide the literature review. Section 3 will be the methodology, followed by Section 4 which is the results and discussions. The final section, Section 5, provides the conclusion.

2. Literature Review

2.1. Demand for Electricity Consumption in Selected African Countries

Power crisis, specifically between 2012 and 2015, impacts electricity consumption in Ghana [33]. Demand for electricity has been attributed to significant population growth leading to increased urbanization, technology, growing per capita income, structural change in the economy, government policy of providing subsidies and rural electricity drive of government. It was noted by [34] that economic activity, urban growth, structural change and income exerted weighting effects on electricity use in Ghana relative to efficiency issues. Electricity usage influences households and firms in many ways [35].

Households demand electricity for lighting which enhances educational outcomes, setting new businesses and for the production of services such as pumping water and accelerating the pace in cooking healthy food. Electricity usage also helps in reallocating time between the day and night which increases the supply of labor time available for work. Among firms, electricity serves as an important input which accelerates the pace of production [36]. There must be access to electricity before any meaningful development opportunity in this era. Electricity supports education. Electricity is the linkage between Africa and the global economy grid. Standard of living in real terms is a function of access to electricity. It is an indispensable source of food that is required for human survival across the globe. Access to electricity is a catalyst for the growth and development of an economy [37].

It is established that changes in GPD had a causal impact on electricity consumption in Africa, ref. [38] using time series techniques, such as autoregressive distribution lag (ARDL) bound, fully modified ordinary least squares (FMOLS) and the partial adjustment model (PAM), analyzed the driving forces of electricity demand in Ghana. It was found that income and urbanization had positive effects on electricity demand [39].

Using the autoregressive distribution lag (ARDL) model, ref. [40] estimated the factors influencing electricity consumption in Nigeria between 1981 to 2017. Their results revealed that major propellers of electricity consumption in the long run in Nigeria are per capita income, population per square kilometer, number of electricity customers as well as electricity shortages. It is reported that 55% of Nigerians lack access to electricity while the 45% connected suffers constantly from power failure. The estimated yearly electricity usage per capita in Nigeria is about 150 Kwh one of the lowest in Africa. Thus, the electricity crisis in
Nigeria threatens to weaken regional and global market competition, obstruct job creation and reduce the growth rate of the economy [41].

Sub-Saharan Africa (SSA) accounts for 13% of the world population but accounts for 4% of the total global energy consumed [42]. Most of the energy consumed is derived from solid biomass such as fuelwood and charcoal which accounts for more than 75% of the total energy consumed in the region. The annual per capita electricity consumption of the 45 SSA countries is the lowest in the world at 518 kWh. About 600 million people in SSA lack access to electricity [42]. It is further revealed that income, urbanization and population are the main determinants of electricity demand in sub-Saharan Africa (SSA). Furthermore, it was revealed that population is the predominant factor behind electricity demand with the highest elasticity [42]. However, the negative impact of urbanization on electricity demand is against our expectations [42].

Moreover, ref. [43] re-investigated electricity consumption determinants in Pakistan particularly economic growth, foreign direct investment and population growth over a 36-year time period. Their study employed the bounds-testing procedure for cointegration, dynamic short-run causality test and Wald-F statistics. The results reveal that determinants of electricity consumption functions are cointegrated and influx of foreign direct investment, income and population growth is positively related to electricity consumption in Pakistan. However, the intensity of these determinants is different on electricity consumption. If there is 1% increase in income, foreign direct investment and population growth, electricity consumption increases by 0.973%, 0.056% and 1.605%, respectively. This infers that income, foreign direct investment and population growth induces an increase in electricity consumption in Pakistan. Ref. [43] were among the first to study the electricity demand determinants with population growth, economic growth and foreign direct investment. With the inclusion of foreign direct investment this current study adds trade openness to study electricity demand determinants among four West African countries.

Demand for electricity is influenced by economic and non-economic factors. In developing countries, the measure of determinants of consumption of electricity are national income, electricity prices and price of alternatives. Others are population, urbanization and industrialization [44].

A distinguishing feature of previous studies from this study is that, in relation to electricity demand determinants, emphasis was placed on electricity consumption, population growth, per capita income, GDP and so on. Most of the studies focus on one country such as [45,46] on Ghana, ref. [43] on Nigeria and ref. [44] on Pakistan. The studies which focused on the determinants of electricity consumption in SSA [43] focused more on population growth, per capita income and urbanization. This current study will examine the determinants of electricity demand in Ghana, Nigeria, Cote d’Ivoire and Senegal in relation to GDP, population growth, foreign direct investment (FDI) and trade openness. The inclusion of FDI and trade openness distinguishes the study from [43]. Furthermore, the pooled OLS method is used to examine data collected between 1980 to 2018 which is different from the usual ARDL methods [47] used for similar studies.

2.2. Trends in Energy Consumption in Ghana, Nigeria, Cote d’Ivoire and Senegal

Despite West Africa’s abundant energy resources, electricity consumption per capita is among the lowest in the world with about 160 kWh consumed per capita annually [17,20,21]. According to [30], poor planning and oversight of the electricity sector has resulted in high cost of electricity in West Africa. Furthermore, ref. [30] stipulate that the high cost of electric power in West Africa is also driven by generation of electric power using fossil fuels. The report further states that West Africa’s retail tariff averages are measured at about USD0.25 per kilowatt-hour, which is more than double the global average and the rate in some developed countries such as the United States (USD0.12/kWh) and much higher comparatively in many developing economies such as India (USD0.08/kWh). This is because many West African countries import petroleum products from international oil markets and are highly vulnerable to fluctuations in oil prices and foreign exchange rates.
In Ghana, electricity consumption peaked at 416 kWh in 1980, but dropped considerably between the years 1982 and 1984. The decline is attributed to the country’s first energy crises experienced in 1982 [19]. The fall in electric power consumption did not last long as consumption increased to 258 kwh in 1986. Furthermore, the quantum of electric power consumed increased from 287 kwh in 1987 to 387 kwh in 1997. Between 1997 and 2007, electricity consumption reduced by approximately 60% from 387 kwh in 1997 to 241 kwh in 2007. Beyond 2007, electricity consumption rose steadily peaking at 375 kwh in 2013 and falling slightly to 351 kwh in 2014. In Senegal, electricity consumption has generally experienced an upward trend over the years. Rising from 71 kwh in the 1970s, electricity consumption peaked at 229 kwh in 2014. On the other hand, energy usage in Cote d’Ivoire rose steadily and peaked at 198 kwh in 1979. Between 1979 and 1984, electricity consumption reduced by approximately 22% but started rising after this drop reaching a level of 174 kwh in 1988. Electricity consumption in Cote d’Ivoire increased by over 50% from 2001 to 2014. Similarly, Nigeria has experienced fluctuations in electricity consumption over the periods. Figure 1 presents the trend in electricity consumption from 1971 to 2014 in Ghana, Nigeria, Senegal and Cote d’Ivoire.

![Figure 1. Energy consumption trends. Source: Adapted from [18,19].](image)

3. Methodology and Data

3.1. Functional Data

This section of the study explains how the functional specifications for firms or an economy are derived. Specifically, the paper applies the Cobb–Douglas production function [48]. Indeed, the production factors is given as:

\[ Q = AK^\alpha L^\beta E^\gamma M^\delta \]  

(1)

where \( Q \), \( K \), \( L \), \( E \) and \( M \) are the output, capital, labor, energy consumption and materials, respectively; \( \alpha \), \( \beta \), \( \gamma \) and \( \delta \) are positive constants.

It is assumed that (i) both cost and production functions exist as dual functions; (ii) an average price and a fixed markup are used to determine the factor price; (iii) the demand of goods and services is a function of price and income; (iv) these functions are specified to reflect the Cobb–Douglas; and (v) cost minimization conditions are assumed when deriving first order conditions.

The energy demand equation can be derived based on these assumptions:

\[ \ln E = \alpha_0' + \alpha' \ln p_k + \beta' \ln p_1 + \delta' \ln p_m + \gamma' \ln p_c + \eta' \ln Q \]  

(2)
\[ a_0' = \frac{-\ln A + \alpha \ln \left( \frac{y}{p} \right) + \beta \ln \left( \frac{y}{p} \right) + \delta \ln \left( \frac{y}{p} \right)}{a + \beta + \gamma + \delta}, \]
\[ \beta' = \frac{\beta}{a + \beta + \gamma + \delta}, \]
\[ \delta' = \frac{\delta}{a + \beta + \gamma + \delta}, \]
\[ \gamma' = \frac{\gamma}{a + \beta + \gamma + \delta}, \]
\[ \eta' = \frac{\eta}{a + \beta + \gamma + \delta}. \]

Since \( a, \beta, \gamma \) and \( \delta \) are positive numbers, one can make an observation from the above notations that \( a', \beta', \gamma' \) and \( \eta' \) are positive numbers, while \( \gamma' \) is a negative number. Based on this, we estimate the relationship between energy demand on one and energy prices, capital, labor and material on the other hand. Following the study [48,49], we specify the demand functions of the economy for each product as follows:
\[ Q_i = f(p_1, p_2, \ldots, p_m, y), i = 1, \ldots, n \]
(3)

where \( p_i \) are prices and \( Y \) is the total income. This function, expressed in logs, is as follows:
\[ \ln Q = \theta_0 + \theta_1 \ln p_k + \theta_2 \ln p_1 + \theta_3 \ln p_m + \theta_4 \ln p_e + \theta_5 \ln p_y \]
(4)

where \( \theta_i \) are negative numbers, for \( i = 1 \) to 4, while \( \theta_5 > 0 \). In a market equilibrium, as in the case of [48]'s study, Equations (2) and (5) can be solved together. That is, if \( \ln Q \) in (2) is substituted with its expressions in Equation (5), the function is written as follows:
\[ \ln E = (a_0' + \eta' \theta_0) + (a' + \eta' \theta_1) \ln p_k + (\beta' + \eta' \theta_2) \ln p_1 + (\delta' + \eta' \theta_3) \ln p_m + (\gamma' + \eta' \theta_4) \ln p_e + \eta' \theta_5 \ln Y \]
(5)

Equation (6) can be simplified as:
\[ \ln E = a_0'' + (\alpha)'' \in p_k + (\beta)'' \ln p + (\delta)'' \in p_m + (\gamma)'' \ln p + (\eta)'' \in \{e\} \]
(6)

where
\[ a_0'' = a_0' + \eta' \theta_0, \]
\[ a'' = a' + \eta' \theta_1, \]
\[ \beta'' = \beta' + \eta' \theta_2, \]
\[ \delta'' = \delta' + \eta' \theta_3, \]
\[ \gamma'' = \gamma' + \eta' \theta_4 \]

In Equation (7), it is assumed that factor prices and total income determine demand. Based on the signs of \( \gamma' \), \( \eta', \theta_4 \) and \( \theta_5 \), it can be seen that, \( \gamma' < 0 \) while \( \{\eta\}' > 0 \). The comprehensive discussion of the signs of coefficients can be found in [48,49].

In Equations (7) and (8), the prices of other inputs are omitted in order to link prices and income directly to the demand for energy:
\[ \ln E = a_1 + a_2 \ln p_e + a_3 \ln Y \]
(7)

Similarly, Equation (2) can be reduced to Equation (8), if \( Y \) is substituted by \( Q \). Previous studies such as [48,49] end up with Equation (8) because they assume that the price of capital goods is linearly dependent on GDP deflator and the price of labor is proportional to GDP deflator.

In this paper, the electricity demand model developed by [34,35] in analyzing the primary drivers or factors that affect electricity consumption is adopted. The electricity demand model employed in the work of [47], is described in Equation (9) as:
\[ EC = a_0 + a_1 GDP_{it} + a_2 POP_{it} + a_3 FDI_{it} + a_4 TRADE_{it} + a_5 INDUS_{it} + a_6 CPI_{it} \]
(8)

where \( EC \) represents electricity consumed, \( POP \) denotes population, \( FDI \) represents foreign direct investment inflow, \( TRADE \) denotes trade openness, \( INDUS \) represents industry value added (% of GDP) used as a measure of industry efficiency and \( CPI \) denotes consumer price index and it is employed as a proxy for electricity prices.
According to the works of [50], it is argued that population growth coupled with an increase in real incomes would increase the usage of electrical appliances and thus increase energy consumption.

The model involves incomes calculated by per capita GDP and population growth measured in terms of population total [39] and also asserts that a rise in population results in an increase in electricity consumption.

Furthermore, ref. [51] stipulates that those countries which experience a rise in trade liberalization also observe an increase in energy demand in the industrial and transport sectors. Therefore, trade openness is expected to heighten electricity use [41]. More so, following the study of [52], the inflow of foreign investments will enhance production activities in various sectors of an economy including the industrial and services sectors. This is anticipated to increase electricity consumption. In line with this, FDI inflow is included as an instrumental variable in the model.

The pressure on energy demand is likely to increase as an economy transition to more energy-intensive sectors [19]. In addition, ref. [53] states that an increase in the share of an industrial or production share will increase electricity consumed in an economy’s overall output. The share of industrial production is thus used as an explanatory variable in overall output.

The price of electricity has an important effect on the consumption of electricity [54]. The analysis also shows that a rise in prices of energy results in a reduction in consumer buying power and hence in fewer household purchases. Similarly, the lower price of electricity increases consumer purchasing power and thus increases the consumer’s electricity purchase. The research used the consumer price index in line with the work of [54] as a measure of electricity prices.

3.2. Empirical Model

In order to account for temporal autocorrelation, the study adopted a standard panel growth framework, reducing possible false regressions, which can lead to inaccurate inferences and estimates. The fundamental equation used for the study is specified as:

$$y_{it} = x_{it} + \beta + \varepsilon_{it}$$  \hspace{1cm} (9)

where

$$\varepsilon_{it} = \mu_i + v_{it}$$

That is, the error term in Equation (9) is decomposed into two components with the first component tests the basic effects of the country not observed, while the second component is the error term.

Equation (10) can therefore be rewritten as:

$$y_{it} = \mu_i + BX_{it} + v_{it}$$  \hspace{1cm} (10)

where \((i)\) denotes the countries under study, \(t\) denotes years, \(y\) is a proxy for electricity consumption, \(y (i, t – 1)\) is a lagged proxy for electricity consumption, \(x\) is a matrix of all explanatory variables, \(\mu_i\) is an unobserved country-specific time-invariant effect and \(v_{it}\) is an idiosyncratic error term.

From Equation (11) and the standard panel equation in (10) and based on the description of the variables and analytical interests, the model to be estimated is written as:

$$LEC = a_0 + a_1LGDP_{it} + a_2LPOP_{it} + a_3LFDI_{it} + a_4LTRADE_{it} + a_5LINDUS_{it} + a_6CPI_{it}$$  \hspace{1cm} (11)

where:

- \(LEC\) denotes the natural logarithm of electricity consumption;
- \(LGDP\) represents the natural logarithm of gross domestic product per capita;
- \(LPOP\) denotes the natural logarithm of population growth;
- \(LFDI\) denotes the natural logarithm of foreign direct investment;
- \(LTRADE\) represents the natural logarithm of trade in goods and services;
LINDUS denotes the natural logarithm of industry value added; LCPI denotes the natural logarithm of consumer price index; \( i \) is the individual country identifier; \( t \) is the time period.

3.3. Variable Description, Measurement and Expected Signs

3.3.1. Electricity Consumption

The cumulative amount of electricity used for different purposes in one area is determined by electricity consumption. This includes electricity used by the manufacturers, households, businesses and all other segments of the nation. Electricity consumption is expressed in billions of kilowatts per hour. Electricity consumption is in the order of a billion kilowatts per hour, following [55]. It is later denoted by \( EC \).

3.3.2. Gross Domestic Product per Capita

\( GDP \) measures over a period, usually one year, the total quantity of goods and services an economy produces. The level of economic activity in an economy is calculated by \( GDP \). For a given year, the entire population is divided into a single nation by \( GDP \) per capita. \( GDP \) is used as a variable per capita in the analysis because it is capable of capturing the living conditions of a specific country [19,38]. It has been reported that \( GDP \) per capita is expected to have a beneficial effect on energy use [19,38].

3.3.3. Total Population

The number of persons in a country, whatever their legal status or citizenship, is defined as total population. It excludes, however, refugees who are not regarded as permanent citizens but are considered part of their country of origin. For the study of the determinants of electricity use, studies such as [56], the total population has been incorporated as a variable. Population is expected to have a positive effect on the energy usage quantum.

3.3.4. Foreign Direct Investment

This tests investments in business interests located in another jurisdiction made by a company or entity in one jurisdiction. It is calculated as net inflows in USD for foreign direct investment. In line with the analysis of [57], \( FDI \) is used as a control variable. The effect on electricity use is expected to be beneficial.

3.3.5. Trade Openness

Trade involves trade between countries in goods and services. Trade openness is the amount of goods and services calculated as a percentage of gross domestic product exports and imports. Trade openness as a component in examining the main drivers of electricity usage has been used in trials including [57]. The amount of electricity consumed is expected to be positively affected by trade openness.

3.3.6. Industry Value Added

Industry value added constitutes the net output of the manufacturing sector after all outputs are added and intermediate inputs are subtracted. This is calculated as a GDP share and is projected to have a positive impact on the consumption of electricity. In accordance with [40], it is used as an explanatory variable.

3.3.7. Consumer Price Index

The consumer price index represents increases in the cost of purchasing a basket of products and services to the average customer that can be set or adjusted at prescribed intervals, such as annually. This tracks the average price shift customers are paying over a time. In accordance with [43,45], it is used as an explanatory variable.
3.4. Data and Source

The main purpose of the study is to investigate the factors influencing West African electricity consumption. Data ranging from 1980 to 2018 were employed in accordance with this objective. The selection of the period is based on the non-availability of data for periods after 2018. More so, four West African countries are used in the research. The nations are Ghana, Nigeria, Senegal and the Ivory Coast. The choice of these countries is based primarily on the unavailability of data as well as the fact that the selected countries have a higher proportion of their population with access to electricity relative to other countries in West Africa.

Statistics are derived from the World Bank Development Indicators on main macroeconomic variables such as energy consumption in kilowatt per hour, population, GDP per capita in constant US dollars 2010, trade accessibility measured as a percentage of GDP, business value added measured as a percentage of GDP, foreign direct investment inflows into current US dollars and consumer price index [18].

3.5. Estimation Techniques

3.5.1. Sample Techniques

The structure of the data for the study justifies the use of panel data estimation techniques to conduct the required analysis. Panel data give data that are more informative, more variable and are good for the study of more complicated models. In order to evaluate the variables of interest given a panel data model, one method is pooling all the cross-sectional and series data without distinguishing them and using any of the panel estimation frameworks such as the ordinary least squares for static effects estimation or generalized least squares for random effects evaluation [58]. In pooled OLS regression, the study basically pools all variables and evaluate the grand regression, whiles overlooking the cross-section and time series nature of the data, in which instance the error term captures all inclusive. Hence, since all the observations under this model were pooled together, it tends to camouflage the heterogeneity or individuality that exists between the variables. The unobserved effect model with \( m \) observed explanatory variables and is given as:

\[
Y_{it} = \beta_1 X_{i1t} + \beta_2 X_{i2t} + \beta_m X_{imt} + \gamma_1 Z_{i1t} + \cdots + \gamma_n Z_{in} + \alpha_i + \mu_{it} \quad t = 1, 2, T
\]

where \( i \) represents the cross-sectional unit and \( t \) as time period.
\( \mu_{it} \) = the error term changing over time and influenced by \( Y_{it} \).
\( \alpha_i \) = all the unobserved and time-constraint factors influencing \( Y_{it} \).

The specific model of this study on examining the determinants of energy consumption using the panel data analysis is given as:

\[
LEC_{it} = LGDP_{it} + LPOP_{it} + LFDI_{it} + LTRADE_{it} + LINDUS_{it} + CPI_{it} + \alpha_i + \mu_{it} \quad (13)
\]

In the process for the pooled ordinary least squares to produce a constant estimator of \( \beta_j \), the framework should satisfy the postulation that the effect, \( v_{it} = \alpha_i + \mu_{it} \) is uncorrelated with \( X_{iit} \). According to [46], though there is no relationship between the idiosyncratic error \( \mu_{it} \) and \( X_{iit} \), the POLS is biased and inconsistent if there is no correlation between \( \alpha_i \) and \( X_{iit} \).

3.5.2. Fixed Effects and Random Effects Model

The literature in econometrics assumes two different connections between the time-invariant error term and the explanatory variables. These assumptions result in the fixed effect (FE) and random effects (RE) framework. In random effects framework, the unobserved variables are presumed to be uncorrelated with (or strongly, statistically independent of) all observed variables. Specifically, the RE framework shoulders that the unobserved country-specific time-invariant effects are uncorrelated with the explanatory variables.
The framework is used when variations across countries are assumed to be random and uncorrelated with the independent variables. Expressed mathematically as:

\[ \text{cov}(\mu_i, v_{it}) = 0 \] (14)

The country explicit features are incorporated as descriptive variables in the equation to be estimated with regard to the RE model. The country-specific characteristics may include cultural differences, differences in climatic conditions, differences in endowment of natural resources, differences in approach or implementation of policies regarding the protection of the environment and geographical variables mostly exclusive and for each country and are time invariant as well. The postulation of uncorrelated country-specific time-invariant error terms and the regressors is upheld by the RE model and as such allows for time-invariant factors to be included in the framework as independent factors. The random effect estimator is linked to the generalized least squares estimator which considers the serial correlation:

\[ \text{Cov}(X_{itj}, \alpha_i) = \sigma^2_{\alpha} + \sigma^2_{\mu} \]

where \( \sigma^2_{\alpha} \) is the variance of \( \alpha_i \) and \( \sigma^2_{\mu} \) is the variance of \( \mu_i \). If the regressor content restricts exogeneity when there is no serial correlation or no unobserved effect, \( \sigma^2_{\alpha} > 0 \) and \( \mu_i \) are non-autocorrelated and homoscedastic, the random effect model will be efficient and appropriate.

The fixed effects model on the other hand assumes that the country-specific time-invariant effects are correlated with the instructive variables and therefore controls for these effects. Stated differently, the fixed effects model controls for or partials out the effects of the time-invariant with time-invariant effects. This is factual whether the variable is clearly measured or not. The fixed effects model is specified in a general form as:

\[ Y_{it} = \beta_0 + x'_{it} \beta + v_{it} \] (15)

The framework is appropriate on the supposition that countries that possess special individual features, unique to the particular countries, and are time invariant. The time-invariant effects from the valuation are eliminated by using the within conversion to demean the variables. The within subject means that for each factor, both the \( X \) and the \( Y \) are subtracted from the observed values of the variables. Therefore, within each subject, the demeaned variables have a mean of zero. The within transformation process is represented in Equation (16).

\[ y_{it} - \bar{y}_i = (x_{it} - \bar{x}_i) \beta + (\mu_i - \bar{\mu}_i) + (v_{it} - \bar{v}_i) \] (16)

where

\[ \bar{y}_i = \frac{1}{T} \sum_{t=1}^{T} Y_{it}, \bar{x}_i = \frac{1}{T} \sum_{t=1}^{T} x_{it}, \bar{v}_i = \frac{1}{T} \sum_{t=1}^{T} v_{it}, \bar{\mu}_i = \mu_i \]

In the within conversion process as defined in Equation (16), the variable means are calculated and afterward deducted from their actual values. In view of the fact that the country-specific error terms \( (\mu_i) \) do not change overtime, its mean value \( (\bar{\mu}_i) \) is identical to the definite value. This progression removes the country-specific effects from the equation. The existence of heteroscedasticity would therefore favor the use of the fixed effects model because it adopts heterogeneity in the error terms across the countries.

3.5.3. Hausman Test

A momentous apprehension when making a choice in selecting a fixed effects or random effects method is reliant on whether \( \alpha_i \) is interrelated with each of the explanatory variable, \( X_{itj} \). A test suggested by [59] chooses between the fixed effects and random effects model. Green and Winik (2010) opined that the Hausman test relates one estimator which is consistent irrespective of whether the null hypothesis is true or not to another estimator.
consistent under the null hypothesis. The null hypothesis states that the error term is fixed against the alternative that the error term is random. In certain cases, if the Hausman test favors, the random effect estimator shows more efficient results than the fixed effect estimator does. Additionally, time-varying regressors are calculated for the Hausman test statistics. The null hypothesis states that there is no association between the regressors and results (heterogeneity), and that the random effect is more fitting. The alternative hypothesis notes that the regressors and the results are correlated, and thus the best model is the fixed effects model.

The Hausman test is statistically relevant if the null hypothesis is denied. The fixed effects model is the most appropriate estimation technique in this situation. On the other hand, if the Hausman test is statistically insignificant, the null hypothesis is not dismissed. In this case, the idea of a random effect is more fitting. The Hausman–Taylor estimator allows the time-invariant variables to be defined for the coefficients. Nonetheless, this estimator’s implementation needs certain time-variant and time-invariant exogenous variables, so all regressors are uncorrelated with the idiosyncratic term of error. The basic idea behind this estimator is to use the average values of the exogenous variables of the time version and the deviations from those averages as instruments for the endogenous variables’ invariant in time. The Hausman test statistics are disseminated under the null hypothesis as a Chi-square random variable, with notches of independence equal to the number of regressors. The formula of the Hausman test statistic is given as:

$$H = (\hat{\beta}_{REM} - \hat{\beta}_{FEM})'V^{-1}(\hat{\beta}_{REM} - \hat{\beta}_{FEM})$$

where $\hat{\beta}_{REM}$ and $\hat{\beta}_{FEM}$ are the fixed and random effect estimators, respectively, and

$$V = Var(\hat{\beta}_{FEM}) - Var(\hat{\beta}_{REM})$$

3.5.4. Heteroscedasticity

The review of econometric literature explicitly points out that when the variation in error terms varies through experiments, the problem of heteroscedasticity arises. Ref. [60] opines that the outliers in variables, incorrect transformation of results, incorrect functional types and exclusion of essential variables affect the variance of the error terms of the reliant variables not to be constant. The likelihood ratio test will be applied to detect the existence of heteroscedasticity within the sample. Using reliable standard errors to solve the problem [61].

3.5.5. Autocorrelation

Autocorrelation is said to be existent when the error terms from different periods (or cross-section observations) are correlated. The problem of autocorrelation leads to biased standard errors and inefficient regression estimates. It is necessary to detect autocorrelation in the idiosyncratic term for error in this respect. For this research, autocorrelation is tested using Wooldridge’s propounded [62] test. According to [63], the Wooldridge test requires few assumptions and this makes autocorrelation useful. The use of robust standard errors can solve autocorrelation [52]. In line with this, once it is observed, the study employs robust standard errors in solving the autocorrelation problem.

4. Results and Discussion

4.1. Descriptive Analysis

This part of the study elaborates results derived from descriptive analysis of the variables used in the study. Essentially, the descriptive analysis is important as it gives an idea with regard to the characteristics and other qualities of the variables. Table 1 presents the summary descriptive statistics.
Table 1. Descriptive statistics.

| Variables                      | Mean  | Standard Deviation | Minimum Value | Maximum Value |
|--------------------------------|-------|--------------------|---------------|---------------|
| Electricity consumption        | 5.07  | 0.48               | 3.93          | 6.03          |
| Population                    | 16.98 | 1.01               | 15.54         | 19.09         |
| GDP                            | 24.16 | 1.2                | 22.55         | 26.87         |
| Foreign direct investment      | 0.21  | 1.06               | −3.09         | 2.25          |
| Trade                         | 3.95  | 0.55               | 1.84          | 4.75          |
| Industry value added           | 3.13  | 0.27               | 1.83          | 3.67          |
| Consumer Price Index           | 3.39  | 1.8                | −2.81         | 5.54          |

Source: Authors’ computation based on STATA 13 (2022).

The results from the descriptive statistics, as reported in Table 1, show that average electricity consumption in the four countries hovers around 5.07 kWh per capita, which is low relative to that of developed countries. The maximum amount of electricity consumed is 6.03 whereas the minimum is 3.93. The results further indicate that averagely, the economies of Nigeria, Ghana, Cote d’Ivoire and Senegal expand by 24.16 with a minimum and maximum value of 22.55 and 26.87, respectively. This indicates a rather impressive performance for these countries. Consumer price index is the most dispersed variable as it recorded the highest standard deviation of 1.80. The mean recorded is 3.39. The findings further reveal that the foreign direct investment measured by proportion of GDP that represents net inflows records a mean, standard deviation and maximum values of 0.21, 1.06 and 2.25, respectively. This indicates that foreign inflows have not been quite significant given the rates of foreign investments. Furthermore, trade openness records a mean value of 3.95 and a standard deviation of 0.55. The minimum and maximum values are 1.84 and 4.75, respectively. Total population averages 16.98, records a standard deviation of 1.01 as well as a maximum value of 19.09. Industry value added is the least dispersed variable as it records the least standard deviation of 0.27. The mean was observed to be 3.13.

4.2. Time Effects Results

The central aim of the study is to investigate the determinants of the consumption of electricity. In line with this, the study investigates if time is of importance in the analysis. This is carried out in order to ascertain the stability of the regression function over time. The null hypothesis is that time is not of the essence in the contradiction of the alternative hypothesis that time is of importance. The results are reported in Table 2.

Table 2. Results for time effects.

| F (34, 91) = 4.03 | Prob > F = 0.00 |
|-------------------|-----------------|

Source: Authors’ computation based on STATA 13 (2022).

From Table 2, it is evident that the probability value of 0.00 is highly significant. As such, the study rejects the null hypothesis that time is not important. Therefore, the study controls for time in the regression analysis.

4.3. Breusch and Pagan Test for Random Effects Results

For unstable panels, the modified Breusch and Pagan LM test for random effects is carried out to determine whether there is statistical significance for the study to pool or not to pool [53]. The null hypothesis implies that there are no random individual effects and for that matter the pooled regression is appropriate. The results are reported in Table 3.

Table 3. Results for Breusch and Pagan test for random effects.

| Prob > Chibar2 | 1.00 |
|----------------|------|

Source: Authors’ computation based on STATA 13 (2022).
The results indicate that the probability value of 1.00 is not significant and therefore the study fails to reject the null hypothesis that there are no random individual indifferences among the countries. The conclusion therefore is that the four countries under consideration have no significant differences and, in this regard, the pooled regression technique is appropriate.

4.4. Regression Results of Pooled OLS

The study examines the key factors that determine electricity consumption in West Africa. The results are presented in Table 4.

Table 4. Results from pooled OLS estimation.

| VARIABLES                      | Pooled OLS     | Fixed Effect | Random Effect |
|--------------------------------|----------------|--------------|---------------|
| Population                     | 0.97***        | 0.97***      | 0.11          |
|                                | [0.21]         | [0.21]       | 0.20          |
|                                | (0.00)         | 0.00         | 0.58          |
| GDP                            | 0.74***        | 0.74***      | −0.09         |
|                                | [0.17]         | 0.17         | 0.19          |
|                                | (0.00)         | 0.00         | 0.60          |
| Foreign Direct Investment      | 0.11***        | 0.11***      | 0.17          |
|                                | [0.04]         | 0.04         | 0.04          |
|                                | (0.01)         | 0.01         | 0.00          |
| Trade                          | 0.72***        | 0.72***      | 0.57          |
|                                | [0.09]         | 0.88         | 0.11          |
|                                | (0.00)         | 0.00         | 0.00          |
| Industry Value Added           | 0.76***        | 0.76***      | −0.82         |
|                                | [0.16]         | 0.16         | 0.16          |
|                                | (0.00)         | 0.00         | 0.00          |
| Consumer Price Index           | −0.42***       | −0.42***     | −0.15         |
|                                | [0.04]         | 0.04         | 0.04          |
|                                | (0.00)         | 0.00         | 0.00          |
| Constant                       | 3.67           | 6.25         | 6.25          |
|                                | [1.02]         | 1.33         | 1.33          |
|                                | (0.00)         | 0.00         | 0.00          |
| Prob > F                       | 0.00***        |              |               |
| R-squared (within)             | 0.79           |              |               |
| Likelihood Ratio Test for      |                |              |               |
| Heteroscedasticity             |                |              |               |
| Prob > Chi2 = 0.00             |                |              |               |
| Wooldridge Test for Autocorrelation |            |              |               |
| Prob > F = 0.02                |                |              |               |

Source: Authors’ computation based on STATA 13 (2022). Note: *** indicates significance at 1%. Robust standard errors are in parenthesis, probability values are in brackets.

The results from the pooled OLS are reported in Table 4. The probability value of 0.00 is highly significant and this implies that the model is robust. The overall R-squared value of 0.79 implies that the independent variables, GDP, population, foreign direct investment, trade openness and industry value added, account for approximately 79% of the variations in electricity consumption. The study employs the Wooldridge test and the likelihood ratio test in testing for autocorrelation and heteroscedasticity, respectively. The Wooldridge test generates a probability value of 0.02 and this is highly significant. Therefore, the null hypothesis of no autocorrelation is rejected. Similarly, the null hypothesis of homoscedasticity is rejected as the likelihood ratio test generates a probability value of 0.00. The study controls for autocorrelation and heteroscedasticity by generating robust standard errors.

The results indicate that GDP per capita has a positive and statistically significant connection with electric power consumption in West Africa. A 1% increase in the GDP
per capita increases the amount of electricity consumed by approximately 0.74%. This finding is collaborated by the study of [3,19,38,54]. It however contradicts the findings of Shaari et al. (2013) [59].

It was discovered by [3] that GDP has a significant beneficial effect on the use of electricity. Therefore, an increase in economic activities would increase electricity use. Similarly, the positive association between GDP and the consumption of electricity is confirmed by [64] by affirming that when incomes grow, consumers and firms increase demands for electrical devices and consequently consume more energy. Again, Adom et al. (2012) [18,43] concluded that both short- and long-term electricity use is being increased in both production and real income propels. Additionally, Shaari et al. (2013) [59] noted, however, that GDP has no major effect on the quantity of energy consumed in Malaysia.

A possible reason for the statistically significant and optimistic relationship between GDP and electricity consumption is that with an increasing economy, income rates are rising and people are able to afford additional energy services [17]. In other words, people will increase their energy use by using technology as revenues increase. In addition, as the economy develops, the business climate is generally strong, attracting investors to the country to build electricity-consuming industries.

The results indicate that the free trade relationship with the use of electricity is positive and statistically important. The results show that the more transparent an economy becomes, the more energy it consumes, Hasson and Masih (2017) [60] confirmed this finding. Aissa et al. (2014) [61] do not demonstrate the relationship between production and renewable energy uses and between trade (such as exports or imports) and short-term use of renewable energy. The relation between trade liberalization and electricity consumption was explored by Ghani (2012) [62]. The study found that trade freedom does not affect the quantity of energy consumed significantly. The trade in goods and services, as defined by Ghani (2012) [62], has a strong and significant connection to electricity consumption. The relationship between free trade and energy use in 15 Asian nations was also examined by Nasreen and Ozturk (2017) [63]. The results showed that openness to trade has a positive connection to the use of oil. Similarly, Cole (2006) [38] investigated the relation between market openness and electricity consumption and found that trade had a positive effect on the consumption of electricity. The study argued that trade liberalization enhances economic growth and thus increases the use of electricity. However, trade liberalization promotes capitalization, which in effect raises the use of electricity. Jena and Grote (2008) [64] established, in the same way, that commercial transparency increased industrial operations, contributing to an increase in the use of electricity. Cole (2006) [38] maintains that trade openness offers an incentive for emerging countries to import advanced technology from the developed world, thus increasing the domestic consumption of electricity.

The findings further show that foreign direct investment has a positive and statistically relevant impact on the use of electricity. The results indicate that a 1% rise in foreign direct investment inflows raises electricity usage by 0.11%. The analysis of [63] supports this result. However, it contradicts [62], as this study found that foreign direct investment inflows have a detrimental impact on energy consumption. Thus, an increase in foreign direct inflows reduces the amount of energy consumed [65]. In other words, the influx of foreign direct investment would lead to the implementation of new technologies, which would increase energy efficiency and therefore reduce the amount of electricity needed for productive activities. Azam et al. (2015) [66], however, argue that FDI inflows are propelling demand in the manufacturing and service sectors. Such sectors thrive on the use of energy and hence an increase in development activities in these industries increases the use of energy.

The study also indicates a positive correlation between industrial output and electricity consumption. The findings show that an increase of 1% in industrial output raises the amount of electricity consumed by about 76%. Adom et al. (2012) [18] collaborates on this observation. Adom et al. (2012) [18] presented evidence indicating that structural shifts in an economy caused by a rise in the share of GDP in the sector lead to an increase
in electricity use. Similarly, ref. [64] used their share of total GDP in the industry as an indicator of economic changes as they move toward the electricity-intensive industries. The study suggests that energy use rises as economic industrial activities intensify [67].

The findings reveal that consumer price index has a negative and significant influence on electricity consumed. The results show that a 1% increase in prices reduces electricity consumption by 0.42%. This finding is confirmed by the study of Mensah et al. (2016) [68]. However, it contradicts the findings of Amusa et al. (2009) [69]. Mensah et al. (2016) [68] found that the price of electricity negatively impacts electricity consumption. However, Amusa et al. (2009) [69] found that electricity prices do not significantly influence electricity consumption.

Furthermore, the results indicate that population growth has a positive and statistically significant relationship with electricity consumption. A 1% increase in population increases the quantum of electricity consumed by 0.53%. This finding is supported by many empirical studies including that of [3,19,38].

It was discovered by [3,19] that population growth has a positive and significant effect on electricity consumption and it is concluded that an increase in population propels electricity consumption. Similarly, ref. [36] found that population growth is a major determinant of electricity consumption. Specifically, the study finds that a 1% increase in population increases electricity consumption by 1.02%. More so, refs. [38,70] found that an increase in population increases the amount of electricity consumed. This implies that population growth is important in determining the quantum of electricity consumed. According to [38,70], as a population grows, more electricity will be required for productive activities and this enhances electricity consumption.

5. Conclusions

The aim of the study is to investigate the determinants of electricity consumption in Cote D'Ivoire, Ghana, Nigeria and Senegal. The research was carried out on four countries in West Africa in line with this core objective and these are Ghana, Nigeria, Cote d'Ivoire and Senegal. The study focuses on these countries as the largest proportions of their populations, more than 50%, have access to electricity. A time-period panel data ranging from 1980 to 2018 is used in the study, having selected the countries. Moreover, the study used the pooled OLS technique as the tool of estimation.

In line with the objects of the study, the findings indicate that population growth has a positive and significant relationship with electricity consumption. Similarly, the study finds that GDP has a positive and statistically significant connection with the quantum of electricity consumed. The study also finds that trade openness has a positive and statistically significant influence on electricity consumption. Foreign direct investment is found to have a positive influence on electricity consumption. The results further reveal that industry output has a positive impact on the amount of electricity consumed. Consumer price index has a negative and significant influence on the quantum of electricity consumed.

The study revealed that population growth, economic growth, FDI and trade openness all have a significant and positive relationship with electricity consumption. Given that there is a rapid increase in the populations of West Africa as projected by the [22], the World Bank projecting a promising economic outlook, the study recommends that key energy efficiency policies as related to demand-side management (DSM) projects should be implemented to ensure that consumers contribute to the power supply value chain in stability and reliability targets.

Furthermore, there is the need for policymakers to vigorously implement energy efficiency measures and policies targeted at managing the demand of electricity arising as a result of population growth. Effective energy efficiency policies are capable of enabling consumers to contribute to the power value chain and in the immediate situation there will be efficient utilization of household electricity demand or reduction in electricity intensity in production.
Again, this will introduce consumer demand-side management schemes in that the use of demand response measures in the form of penalties or incentives to influence or adjust energy consumption pattern of electricity users. This measure is capable of influencing the energy usage and conservation behavior of consumers. Consumer conservation measure is key in this regard and this will require serious behavioral change to drastically influence energy demand.

The study also finds that consumer price index has a negative influence on electricity consumption. Consumer price index represents the general prices of goods and services in a country. The findings suggest that electricity price has a negative relationship with electricity demand. As a result, there is the need for countries to vigorously diversify their energy supply mix by transitioning to affordable sources of energy. As demand continues to rise as a result of population growth and economic growth, the transition to more affordable and reliable energy options cures any negative outcome of price on demand for electricity.

The study is limited in that four countries are considered which means that macro-level analysis is undertaken. A micro-level study is encouraged for each of the four countries to ascertain electricity demand determinants using the same factors of economic growth, population growth, foreign direct investment and trade openness. Furthermore, studies focusing on incentives and penalties on demand-side management schemes in electricity demand response activities in these four countries are encouraged.

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