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The determinants of electricity access in Sub-Saharan Africa

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ABSTRACT

Low access to electricity consumption distorts development prospects. In some parts of the world, individuals have to live with little or no access to electricity which has prompted decision makers to take considerable actions at increasing access to electricity globally. These actions are important considering the fact that modern energy consumption accelerates economic growth, reduces inequality, poverty, as well as environmental pollution and solid fuel consumption. In spite of these actions, the prevalence of limited access to electricity in Sub-Saharan Africa demands empirical research to ascertain the factors that undermine access to electricity in Sub-Saharan Africa considering the fact that not much has been done empirically in this area. Consequently, the determinants of electricity access in Sub-Saharan Africa was the focus of this study. The methodological framework applied adopted the percentage of population with access to electricity as the dependent variable. The independent variables were constrained by data availability. The findings revealed that several factors have led to the low level of electricity consumption in Sub-Saharan African countries. Income per capita, transmission and distribution losses, proportion of rural population, population density, dependency ratio and savings were found to affect electricity access consistently in Sub-Saharan Africa. The results further revealed that the credibility of government – government effectiveness has also hindered electricity access in Sub-Saharan Africa. Access to electricity as revealed by the results is a normal and necessary good. The findings have considerable lessons for policy interventions that will aid in reducing poor electricity consumption in Sub-Saharan Africa.

Keywords: Electricity access, Regional development, Rural development, Government effectiveness, Sub-Saharan Africa,

JEL Classification: L94, O18, R58

1. Introduction

Energy, the catalyst as well as the lubricant that drives developing and developed economies to the path of growth. It is the illumination that illuminates the global village. Critically, reliable supply of electricity is the needed element for sustained economic development and improved quality of life for the teeming population of Sub-Saharan Africa (Wohlgemuth and Turkson, 2001). Expanded access to adequate, reliable, efficient, secure, environmentally responsive and affordable energy is a key element in Africa's quest to achieve sustained economic growth (Iwayemi, 2008). In spite of the essentiality of energy as well as the emphasis on energy accessibility as the main driver of economies in terms of economic growth, wealth creation, poverty reduction, food security, unemployment reduction, improved health status and reduction in inequality; several economies, Sub-Saharan African (SSA) countries in particular are trapped in the web of low access to modern energy (electricity) which is often referred to as energy poverty as revealed by energy ladder.

As much as there is no conventional definition for poverty as well as what constitutes poverty in the literature, there is no consensus definition for energy poverty. However, in spite of the variants as regards the conceptual definition and measurement of energy poverty, there is an hypothesized agreement in recent times that looks critically into the availability, accessibility and the affordability of modern energy service as against traditional form of energy. This is implied in the energy ladder model in which the transition from poorer and inefficient source of energy to a much cleaner and efficient form of energy is tenable (Defries and Pandey, 2009; Aran *et al*., 2011; Masera *et al.*, 2000). This model simply reveals that electricity is at the highest rung of the ladder. Nonetheless, there is also the existence of the engineering approach or the temperature approach which is the earliest approach of measuring energy poverty and the income approach which measures energy poverty as a situation in which a consumer expend more than one-tenth of his income on energy (Lewis 1982; Boardman 1986; Clinch and Healy 2001; Karekezi 2002; Waddams *et al*. 2007).

Access to energy sometimes do not rule out energy poverty. In a scenario where households have relatively higher access to high carbon energy services such as fuel wood and charcoal as against low carbon energy (electricity), the households are termed to be energy poor. Energy poverty in a simplified perspective, is the inability as well as the inconsistency of individuals to access electricity at affordable prices given their income. Affordability explicitly captures the ability of the individuals to demand electricity in the presence of intensive power generation. Access to electricity is conventionally accepted in analysing energy poverty. It can be challenging to measure access to different forms of energy service. "Access" is often times measured simply as the provision of a connection to an electric grid (Bast *et al.*, 2011). This could be attributed to the low carbon emissions generated by electricity and its position in the energy ladder model. For the benefit of this research, we could define energy access from the perspective of the energy ladder model.

The implicit costs of low access to electricity is often times borne by women and children. However, the problem of low access to electricity is not central to women and children. Pollution from solid fuel consumption does not only affect the individual or the household that consumes it. It comes with negative externalities. Agba (2011) argued that it is a serious issue that does not only affect the poor, but also the rich. Low access to electricity is a problem faced by most regions of the world. However, Sub-Saharan Africa remains the most vulnerable region of the world. IAEA (2002) noted that about 1.6 billion inhabitants of which four out of five live in rural areas of the world (precisely, South Asia and Sub-Saharan Africa) lack access to modern form of energy. Approximately, about 2.4 billion people rely on traditional biomass – wood, agricultural residues and dung as their primary source of

energy for cooking and heating (IAEA, 2002). As further pointed out by IAEA (ibid), developing regions need as much as $2.1 trillion and sound policies to reduce the level of energy poverty. In the absence of such new policies, about 1.4 billion people will still lack access to electricity even in the presence of employing such capital for energy sector investments (IAEA, ibid).

Increased consumption of solid fuel has led to substantial carbon-dioxide emissions from solid fuel as a percentage of the total emissions from countries within Sub-Saharan Africa (see WDI, 2012). Scarcity of fossil fuel in most parts of Nigeria combined with rising cost of fossil fuel per litre has led to increased consumption of fuel wood with adverse environmental impact (Iwayemi, 2008). The major problems facing the Sub-Saharan African Power sector are low consumption levels, high electricity cost, unequal access, unreliable supply, and power shortages (Prasad, 2011). There is no doubt that the high electricity cost, unreliable supply and power shortages in Sub-Saharan Africa could be linked to the transmission and distribution losses as a percentage of total output considering the fact that relatively, on the average countries within the region record much of these losses globally (see WDI, 2012).

Considering the fact that the electricity Sub-Sector in Sub-Saharan African countries is mostly state owned, there is the tendency to attribute the low electrification rate in countries within Sub-Saharan Africa to government ineffectiveness in advocating and implementing credible policies that will lead to increased access to electricity. Again, government regulation may also hinder the participation of private service providers in providing electricity to consumers in such a way that will lead to the minimization of poor access to electricity given the benefits of perfect competition such as low price, increased supply and efficient allocation of resources. There is an increased need for effective government policies in the electricity Sub-Sector of Sub-Saharan African countries owing to the existence of erratic power supply in Sub-Saharan Africa in spite of some of the "white elephant" projects that have been earmarked to eradicate it. For instance, in a bid to address low access to electricity in Nigeria, the Nigerian Electricity Regulatory Commission (NERC) issued two new regulations that empowered local and state governments, as well as communities and investors to generate, transmit and distribute energy across all constituencies in Nigeria. However, according to the commission's statement, as revealed by Ayankola (2012), the regulation will only cater for about 40 percent of the country's population without access to electricity. By implication, such gestures by other Sub-Saharan African countries will not help in reducing the number of people without access to electricity to a manageable figure. Thus, low access to electricity still persists in Sub-Saharan African countries. On this note, this paper aims to find out the factors that determine electricity access in Sub-Saharan Africa.

The rest of this research is structured into three sections. In the next section, we present the econometric methodology and estimation technique. Section three presents the results and discussions, while section four contains the summary of findings, recommendations and concluding remarks.

2. **Methodology and Estimation Technique**

Subject to the identification of factors that affect electricity access; e.g. income, household's size, locality, government effectiveness, transmission and distribution losses, and Weak institutions. The reduced form model of electricity access is adopted as:

$$Access_{it} = \alpha + X'_{it}\beta + \mu_{it} \qquad (1)$$

where $Access_{it}$ is the dependent variable, X_{it} is a k-vector of explanatory variables, β is the short term effects of changes in explanatory variables. It is measured by the common parametric coefficients to be determined, which is of our interest. It should be pointed out that our choice of estimation is based on our policy focus of the entire cross-section and not on specific country(ies) and time. The α parameter is a scalar that represents the overall constant in the model, and μ_{it} are the stochastic disturbance terms for $i = 1, 2, \dots, 21$ cross-sectional units observed for dated periods $t = 1, 2, \dots, 15$. The OLS is adopted for all estimations with emphasis on longitudinal data. Data for Sub-Saharan African (Eastern Africa, Middle Africa, Southern Africa and Western Africa) countries are employed. On the focused data, twenty-one countries from Sub-Saharan Africa are randomly selected based on data availability. For holistic study of the region, all the geographical regions of Sub-Saharan Africa are represented. Since there is no theoretical restriction on our models, linear model specification is adopted. Specifically, our baseline model is specified as:

$$Access_{it} = \alpha + \beta_1 GDP_{it} + \beta_2 Rpop_{it} + \beta_3 Losses_{it} + \beta_4 Govt_{it} + \beta_5 Savings_{it} + \beta_6 PGrowth_{it} + \beta_7 Density_{it} + \beta_8 Dep_{it} + \mu_{it} \quad (2)$$

where Access depicts electricity access measured by electricity consumption per capita. Our overall model specifications captures the impact of finance on electricity access which plays a positive role in the quest to increase electricity access. The relationship between finance and electricity access is an increasing function. It is important to state that for households in countries where per capita income are low such as Sub-Saharan African countries, the relationship between electricity consumption and income is weak to indicate that such households are only meeting their basic energy needs - cooking and lighting (Khandker *et al*., 2012). As he further pointed out, the coefficient of income is the central premise for defining energy poverty line from the electricity demand based approach of energy poverty. In other words, the coefficient of income for energy poor households should be positive but not close to unitary.

Also, the introduction of demographic variables (Rpop – Rural population, PGrowth – Population growth rate, Density – Population density and Dep – Dependency ratio) help in analysing the negative effect of population explosion on electricity access. Reduction in demographic variables mitigates the problem of electricity access. Again, the introduction of transmission and distribution losses explain its contribution to poor access to electricity. Electricity access is a decreasing function of transmission and distribution losses. And finally, the introduction of the institutional variable, precisely government effectiveness elucidates on the quality of governance in addressing utility yielding service such as electricity. It is an increasing function of energy access.

3. Results and Discussions

Model 1 in Table 3.1 accounts for the effect of GDP per capita in ensuring that households consume improved, clean, efficient and modern form of energy as explicitly stated in the theory of energy ladder. Model 2 captures the effect of rural population in the determination of energy poverty. On the other hand, model 3 handles the effect of distribution and transmission losses of electricity, while model 4 looks at the effectiveness of government in providing electricity to the inhabitants of Sub-Saharan Africa. In addition to the economic variable of GDP per capita, model 5 includes savings in analysing the determining factors of access to electricity. Models 6, 8 and 11 include various housesholds' demographic characteristics in explaining electricity access in Sub-Saharan Africa. Models 9 and 10

capture government effectiveness and transmission and distribution losses respectively in analysing electricity access.

The low adjusted R^2 values in models 1, 2, 9 and 10 indicate the effects of important data such as electricity tariff (pricing), poverty and unemployment. Nonetheless, the heterogeneity characteristics of our data also contribute to the lower explanatory power of some of the models. The explanatory power (R^2) of model 9 relative to that of model 10 indicated that the state has contributed more to energy poverty than the transmission and distribution losses that could have resulted through technical inefficiency on the part of the technical crew.

The coefficients of income in all the estimated results were statistically significant. The results further revealed that electricity is a necessary and normal good. Interestingly, the results support the argument of increasing access to electricity as the households income rise. The coefficients of income indicate that a percentage point increase in income will lead to much access to electricity in Sub-Saharan Africa. However, the underlining reasoning surrounding the low coefficients of income in most of the models suggested that a percentage point change in income, ceteris paribus, will lead to a minimal change in the units of energy consumed in a year. In other words, increase in households' income will lead to a modest change in the level of electricity consumption among countries that are relatively poor (see Khandker *et al.*, 2012). The findings revealed that Sub-Saharan African countries are energy poor and that income is a determining factor of energy poverty in the region.

It is interesting to note that the addition of other variables to the model reduces the impact of GDP per capita on access to electricity. The implication of the findings is that income support policies alone in the presence of low access to electricity cannot mitigate the problem associated with low electricity access in the short-run. This is because the problem of electricity access in Sub-Saharan Africa is not solely the problem of the poor but also of the rich. This is further shown in the resultant effect of adding more variables as shown by models 2 – 8 which led to improvement in the adjusted R^2.

The most comprehensive model, labelled 8, obtained an adjusted R^2 of 0.73. In this model, all the variables were statistically significant. The results strongly revealed that there is an interaction of factors that affect energy access in Sub-Saharan Africa. They were not only statistically significant at 1% level of significance, they also maintained "right" sign except savings that had a "wrong" sign in all the estimations, similar to Onyeji (2010) where savings constituted one of the determinants of electricity access. However, the relationship between savings and access to electricity in all the estimated models were not surprising. The results indicate that as households dis-save, they tend to increase the consumption of more efficient and cleaner energy services. Implicitly, the results implied that economic agents often find it difficult to save for investment projects that require large physical capital stock in a region with poor socio-economic condition as Sub-Saharan Africa. Where little savings exist, the tendency to increase such savings on the average in the midst of a basic need such as electricity is often very difficult.

The results on rural population as revealed by models 2 – 8, and 11 inclusive as shown in Table 3.1 maintained the theoretical relationship. The results were also statistically significant at 1% level. The coefficients of rural population depict that ceteris paribus, a percentage point increase in the proportion of rural population will lead to a decline in the per capita electricity consumption in Sub-Saharan Africa. Onyeji (2010) argues that the proportion of people that reside in rural areas is another key determinant of access to electricity in Sub-Saharan Africa as established empirically in this work. In this regard, the link between access to electricity and the proportion of rural population could be attributed to two factors; allocative inefficiency by successive governments that often times are not in the

interest of the rural dwellers, and the fact that the dispersion among households in such locations are often times very wide such that successive governments might think that the costs of rural electrification outweigh the benefits. Nonetheless, if adequate cost/benefit that captures positive and external costs are undertaken, the government of Sub-Saharan African countries will see the need for rural electrification. Walker and Day (2012) view such allocative inefficiency as distributional injustice that was not taken into cognisance during the promulgation of rights. Thus, in the midst of these, increased rural population will worsen access to electricity. Again, it should be pointed out that connection of households with electric grid in the rural areas is more capital intensive. And often times, where there is deregulation, private investors do not like operating in the suburbs because of the low socio-economic power of the inhabitants which will inhibit their ability to pay for electricity consumption.

Our results have equally established an important issue that has long been neglected in the literature. The findings as revealed by the specified models in Table 3.1 indicated that increase in transmission and distribution losses will reduce access to electricity in Sub-Saharan Africa. All the estimated coefficients were not just statistically significant, but at a very low probability level of 1%. It is interesting to point out that such transmission and distribution losses do not only lead to low electricity consumption, it also results to loss of revenue to the region. It is interesting to note that government effectiveness was significant in all the models unlike regulatory quality that had selective significance in the work of Onyeji (2010). The positive and significant coefficient of government effectiveness in Models 4 – 9 and 11 implies that credible and effective government policy interventions could help in increasing electricity access in Sub-Saharan African countries.

It is important to note that the estimated models in Table 3.1 revealed that demographic characteristics such as population growth rate, population density and the dependency ratio affect access to electricity adversely. One of the implications of the results is that the rate of unemployment in Sub-Saharan Africa which is embedded in the high proportion of dependency level is a reason for lack of access to electricity. Also, from the Malthusian ideology, we could deduce that increased population in Sub-Saharan Africa has led to deforestation to meet the energy needs of the people. Again, it should be quickly pointed out that where there is increased ratio of dependency and rural population without a corresponding increase in income, government effectiveness and reduction in transmission and distribution losses, low access to electricity will prevail. The policy thrust today is to reduce population growth in order to reduce the rate of electricity consumption. This will help to conserve electricity for the future in the absent of new alternative sources of electricity.

In the future, increasing electricity supply may be another way to simultaneously boost the electricity consumption in Sub-Saharan Africa. The region may consider the nuclear power for electricity generation to overcome the shortage of electricity supply. However, when nuclear power is at the concern of the region, the optimal combination of nuclear power and other sources of power may be achieved by the calculation using maximum entropy following the work of Sudtasan and Suriya (2014). The region may also learn the danger and warnings of the nuclear power plant from the Fukushima incident in Japan. The information regarding the economic costs and benefits can be learnt from the work of Sudtasan and Suriya (2012) which state that the nuclear power plant can be beneficial to the region only if it can ensure the safety of the operation of the power plant. Another way to generate electricity is the micro electricity generator using gasohol. However, this choice may increase the demand for energy crops and gasohol while reduce the supply of food crops. Its macroeconomic impact can be viewed in the work of Kunanopadon and Suriya (2012).

Table 3.1 Determinants of Energy Poverty in Sub-Saharan Africa

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
GDP	0.51***	0.47***	0.47***	0.32***	0.32***	0.28***	0.24***	0.18***			0.18***
	(16.04)	(14.01)	(14.33)	(7.91)	(7.28)	(5.83)	(4.48)	(3.41)			(3.39)
RPop		-8.21***	-13.28***	-13.43***	-19.38***	-17.69***	-16.33***	-10.80***			-10.75***
		(-2.81)	(-4.57)	(-4.39)	(-5.20)	(-4.75)	(-4.30)	(-2.81)			(-2.79)
Losses			-17.76***	-15.74***	-13.17***	-12.45***	-12.72***	-16.28***		-10.50***	-16.44***
			(-7.09)	(-5.90)	(-4.30)	(-4.11)	(-4.22)	(-5.61)		(-2.95)	(-5.47)
Govt				496.66***	763.07***	699.75***	770.16***	482.57***	988.74***		475.88***
				(5.50)	(6.77)	(6.16)	(6.36)	(3.67)	(11.95)		(3.51)
Savings					-26.38***	-25.44***	-28.00***	-23.50***			-23.37***
					(-4.38)	(-4.73)	(-5.02)	(-4.38)			(-4.31)
Pgrowth						-326.36**	-364.60***				33.89
						(-2.51)	(-2.77)				(0.21)
Density							-3.97	-5.86***			-5.85***
							(-1.62)	(-2.48)			(-2.47)
Dep								-40.27***			-41.60***
								(-5.06)			(-4.11)
Constant	3.99	524.37***	1203.55***	1644.39***	2492.74***	3158.68***	3456.69***	5627.39***	1223.83***	804.14***	5650.41***
	(0.07)	(2.72)	(5.77)	(7.05)	(7.95)	(7.77)	(7.78)	(8.41)	(15.98)	(96.08)	(8.31)
Obs.	293	293	265	208	158	158	158	158	231	266	158
Adj. R^2	0.4675	0.4798	0.5544	0.6175	0.6894	0.6999	0.7031	0.7333	0.3813	0.0282	0.7316
F-Value	257.405	135.680	110.477	84.545	70.689	62.021	54.112	62.669	142.769	8.680	54.492
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.00)	(0.000)	(0.000)	(0.000)	(0.004)	(0.000)
Wald test	247.13	258.52	334.53	392.17	350.94	369.42	366.89	422.96	142.48	10.41	420.20
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)

Note: ***, **, * indicate significance at the 1%, 5% and 10% levels respectively. T-values in parentheses. The parentheses for F-value and Wald test denote P-values.

4. Conclusions

In summary, the evidence suggests that lack of access to electricity in Sub-Saharan Africa is mostly driven by income per capita. Furthermore, the proportion of rural population, government effectiveness, distribution and transmission losses, savings and the rate of dependency ratio were observed to affect electricity access in Sub-Saharan Africa. The macroeconomic effect of access to modern energy stimulates economic growth and retards poverty and inequality. The poor state of Sub-Saharan Africa is the effect of limited access to electricity as is usually the case in rural areas. This could be attributed to several decades of neglect by concerned authorities as well as the high concentration of the population of Sub-Saharan Africa in the rural areas and the financial capacity of the rural dwellers. Lack of access to electricity by rural dwellers have led to negative externalities on the urban dwellers as the quest for rural-urban migration continue to be on the increase in order to benefit from the limited opportunities in the urban centres. The rural-urban drift does not only increase the energy mix in the urban centres, it also leads to the destruction of the natural habitat as a result of the increase in the demand for fuel wood in the urban centres since migration is often times accompanied with more hardship considering the fact that economic opportunities in the urban centres do not grow geometrically as the growth in rural-urban drift. It has equally led to rationing in the presence of no additional expansion of national electric grids as well as poor erratic power supply.

Regulation of energy sector in the midst of weak institutions does not stimulate electricity consumption per capita. The energy sector of Sub-Saharan Africa is highly regulated. Regulation of the sector is often times not in the interest of the masses. Regulation does not stimulate private participation in the sector since deregulation tends to reduce low access to electricity and price of energy in the long run. The findings strongly support that government of Sub-Saharan African countries have to formulate and implement policies that will be geared towards the provision of basic needs to the people, more specifically, the rural dwellers since top-down approach will create a chain of problems in which low electricity access will still be a part.

We evaluated the determinants of electricity access in Sub-Saharan Africa using secondary data. Specifically, it highlighted the determinants of energy poverty in the region. To our knowledge, this is the first work to examine the inclusion of transmission and distribution losses as a determining factor of electricity access in Sub-Saharan Africa. Considering the fact that the quality of government regulation is a subset of government effectiveness, we equally employed the latter in examining the link between electricity access and the state in ensuring provision of basic necessities to the people of Sub-Saharan Africa. The findings revealed that strong institutions reduce low electricity access, while the reverse is the case for weak institutions.

Interestingly, the findings also established that income per capita drives energy transition in Sub-Saharan African countries. It was also deduced from the results that energy is a normal good in Sub-Saharan African countries. In other words, changes in income do lead to positive changes in electricity consumption per capita but not as much as the changes in income. That is to say that income support interventions alone will lead to energy mix in which the consumption of electricity will still be low among Sub-Saharan African residents. Thus, a holistic approach of policies will be the way out from low access to electricity in the region.

The findings also established that an array of demographic factors such as population density, dependency ratio and population density affect access to electricity in Sub-Saharan Africa. As the results revealed, these factors are a decreasing function of electricity access. For savings, the results that were obtained in spite of the fact that they have “wrong” signs have

policy relevance in Sub-Saharan Africa. The results revealed that since access to electricity is a necessity, the failure of government to provide enabling environment that will lead to improvement in per capita income, will lead to dis-saving which is not healthy for developing countries like Sub-Saharan African countries.

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