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Is clean energy prosperity and technological innovation rapidly mitigating sustainable energy-development deficit in selected sub-Saharan Africa? A myth or reality

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Abstract
United Nations Sustainable Development Goals (UN-SDGs) such as access to clean energy (SDG-7), responsible energy consumption (SDG-12) and sustainable economic growth revolves around the subject of human development that resonates with (SDG-8), and among others. Based on these highlights, this study examines sustainable development for the panel of selected Sub-Sahara African countries that are largely plagued with huge energy deficit (energy poverty) and setback in technological innovation. This study leverages on panel econometrics strategies to explore the hypothesized relationship between the outlined indicators for the period 2000-2016 in Sub-Saharan African countries. Empirical results show that human development index (HDI), economic expansion, access to clean energy. and technological innovation exhibits long-run equilibrium relationship. Subsequently, the finding revealed that economic expansion, access to energy and technological innovation in the sampled countries spur higher HDI indices. That is, a 1% increase in economic growth increases HDI by 0.040% and 0.017 % in the short and long run respectively. Thus, we can infer that enhanced sustainable economic growth leads to higher HDI indices which encompases higher literacy rate, better income level and increase life expectancy in both short and long run. In contrary, access to clean energy in the selected blocs dampens HDI index in the short run but the effect is statistically positive (desirable) in the long run.

Keywords: Clean energy technologies; Technological innovation; Sustainable development; Sub-Saharan Africa.

Abbreviations/list of Numenclature

ACCESS-CE: Access to clean energy and technologies for cooking
ACCESS-TI: Access to technological innovation
ARDL: Autoregressive Distributed Lag
CDP: Committee for development
EU: European Union
ECT: Error Correction Term
DOLS: Dynamic Ordinary Least Squares
FMOLS: Fully-modiffied Ordinary Least Squares
GDP: Gross Domestic Product
GMM: Generalized Method of Moments
HDI: Human Development Index
ICT: Information and Communications Technology
IEA: International Energy Agency
IPCC: Intergovernmental Panel on Climate Change
LDCs: Least Developed Countries
PMG: Pooled Mean Group
SDGs: Sustainable Development Goals
SDI: Sustainable Development Index
UNDP: United Nations Development Programme
USD: United States Dollars
WDI: World Bank Development Indicator

1. Introduction

In the recent triennial report of the Committee for development (CDP), a number of the sub-Saharan African countries were included among the world's 46 Least Developed Countries (LDCs), meaning that these sub-Saharan African are low-income economies (United Nations, 2020). Indicatively, since the LDCs are highly vulnerable to shocks arising from socioeconomic and environmental aspects, the structural setbacks to sustainable development in these economies have consistently remained a source of global concern. As countries across the globe chart their paths toward attaining the significant goals of the United Nations' Sustainable Development Goals for 2030, governance in the sub-Saharan African economies are expected to deliberately drive the related polices in order to avoid falling behind with significant gap. Because, among the seven (7) country grouping[1]of the Human Development Index (HDI) values for the period of 1990 to 2017, the countries in the sub-Saharan Africa shared the lowest ranking (United Nations Development Programme, UNDP, 2018). Considering that the HDI arguably out-performs the Gross Domestic Product (GDP) since it accounts for human's three main aspects (health, income, and knowledge), the sub-Saharan Africa countries are largely faced with the menace of low life expectancy, high illiteracy level, and high income inequality or poverty rate.

Since the approach of quantifying human development (by HDI), as against the quantification of the richness of the economy (GDP) is more inclusive (United Nations Development Programme, 2020), salient drivers of human development are expected to catalyse sustainable development. In addition to the dimensions of human development as depicted in the UNDP report (United Nations Development Programme, 2020), extant studies have examined other

[1] Countries are grouped (group of 7) based on the Human Development Index values as: Organization for Economic Cooperation and Development (OECD), Europe and Central Asia, Latin America and the Caribbean, East Asia and the Pacific, Arab States, and the sub-Saharan Africa. The sustainable development of these coutries are also presented in Appendix (Table A1).

specific drivers of human development such as enhanced information and communications technology (ICT), economic policies, socio-cultural and institutional aspects (Binder & Georgiadis, 2010; Asongu & Le Roux, 2017; Asongu, 2018; Osher et al., 2020). While, studies have associated political factors (Gianella, de Assis Machado & Gloppen, 2017), in addition to per capita income and financial development, inflation, natural resource rent and time have been explored as determinants of sustainable development (Koirala & Pradhan, 2020). Importantly, Dincer (2000), Bugaje (2006), Oyedepo (2014), and several other keenly explored the role of energy (especially clean and renewable sources) utilization in the drive for sustainable development. However, access to energy (especially clean sources) (Bhattacharyya, 2012), especially in most African countries (Karekezi, Kimani & Onguru, 2008; Brew-Hammond, 2010; Bazilian et al., 2012; Sokona, Mulugetta & Gujba, 2012) has remained a challenge with less documentation in the extant literature.

Considering the aforementioned motivation, and the spate of energy poverty in Africa, the current study is designed to close potential gap in the literature, especially for the sub-Saharan Africa region. In specific, rather than looking at the more general subject of energy transition vis-à-vis renewable or clean energy to understudy sustainable development, the current study explores the role of access to clean energy and technologies especially for cooking. Alongside, the objective of examining the determinants of human aspects of sustainable development in sub-Saharan Africa is considered from the perspective of technological innovation. Essentially, especially given the mutual exclusivity of energy use and technological innovation such as the internet, the National Geographic (2017) noted that Africa is reportedly 20 years behind the United States since about 25% of the continent's population lack access to internet technology. Moreover, the extent of sustainable development achievement in sub-Saharan Africa is statistically examined from the perspective of economic growth. Thus, given the chart path being employed for the panel of selected sub-Saharan African countries, the current study is conceptually novel and potentially narrow the existing gap in the literature.

By divulging further, the other sections of the study are outlined successively. A review of related studies is detailed in section two. In section three the description of the dataset and methodological approaches were outlined. Section four presents the empirical results. Lastly, we present the summary of the study and offer policy essential policy insights in section five.

2. Literature Review

The conversation on the relevance of energy sector as a catalyst to economic growth is still ongoing, especially the defining effect of energy on macroeconomic variables as observed in the extant literature. Considering the inability of a household to meet immediate energy need-energy poverty (Thomson et al. 2016), Welsch and Biermann (2017) explored the affordability of electric power to household heating, oil and natural gas energy for more than 100,000 selected European Union (EU) countries from 2002 to 2011. The study showed that energy prices have a statical effect on subjective well-being as well as economic impact over the investigated period. Additionally, the study validated the assertion that increase fuel poverty suggests a greater impact of energy prices on well-being. For the case of India, Sadath and Acharya (2017) presented a comprehensive measure of several socioeconomic consequences of energy poverty in India by using Amartya Sens's capability method. The key submission of the study is that the Indian economy suffers from energy poverty which also resonates other forms of deficits like low-income level and economic austerity. In addition, according to Teschner et al. (2020), energy poverty is widely accepted as a complicated situation faced by millions of people globally.

While overwhelming studies have illustrated the nexus of energy access and utilization and economic growth and development (Kraft & Kraft, 1978; Odhiambo, 2009; Kebede, Kagochi

& Jolly, 2010; Ozturk, 2010; Tugcu, Ozturk & Aslan, 2012; Shahbaz, Khan & Tahir, 2013; Ozturk & Acaravci, 2013; Troster, Shahbaz & Uddin, 2018; Adedoyin et al., 2020; Kose et al., 2020), a relatively different dimension has been charted to the drivers of sustainable development (Boulanger & Bréchet, 2005). For instance, Delina and Sovacool (2018) noted the importance of energy access expansion and sustainable energy transitions in the United Nations' agenda on Sustainable Development Goals (SDGs) and Paris Agreement on climate change. In spite of the increasing progress attained in access to energy across the globe, Bhattacharyya (2012) questioned the sustainability or efficiency of the programmes promoting energy accessibility. Specifically, the study infers that sustainable electrification programme is essential for enabling access to clean energy sources that is readily available for cooking and heating. For Africa, precisely, Kemausuor et al (2011) attributes the bane of increased energy accessibility among African countries to inefficient energy policies. Generally, Lee et al (2017) conducted a systemic revie of 107 scientific peer-review studies to examine household energy transitions in the Lower- and Middle-Income Countries (L&MICs). Importantly, the study revealed that access to clean energy is significantly associated with higher household education, incomes, asset holdings, and government subsidy programs. Thus, Lee et al (2017) concludes that households' well-being are significantly improved by access to clean energy. Moreover, the International Energy Agency (IEA) report reiterated that the energy access has consistently galvanized by the trend of declining cost of decentralized renewables, access to affordable energy efficient technologies, and the increasing utilization of mobile platforms (IEA, 2017).

Furthermore, the role of technology through ICT on sustainable development has been expanded in the literature (Hilty & Hercheui, 2010; Mohamed, Murray & Mohamed, 2010; Olise, 2010; Suryawanshi & Narkhede, 2015; Kostoska & Kocarev, 2019). In specific, Asongu and Le Roux (2017) illustrated the role of ICT in inclusive human development for the sub-Saharan African region by investigating a panel of 49 countries in the region over the period of

2000 to 2012. By employing the Tobit regressions approach, the study found that enhancing access to ICT triggers inclusive human development among the panel countries. However, Asongu and Le Roux (2017) found that the effect of ICTs on human development is conditioned on the classification of ICTs and the fundamentals of human development such as income classification, religion, polity stableness, limited land-wealth resources, and legal origins. In similar approach, Asongu and Odhiambo (2019) advanced the sustainable development literature for Africa from the perspectives of a panel of selected 48 countries in the continent. By employing the generalised method of moments (GMM) approach, the study measured ICT utilization from the perspectives of internet, mobile phone, and fixed broadband penetration while employing the Gini coefficient, Atkinson index, and Palma ratio as indicators of inequality. Thus, the study found that internet and fixed broadband usage show a net effect of reducing the Atkinson index and the Gini coefficient while the Palma ratio is reduced by mobile phone and internet penetration. Meanwhile, Mohamed, Murray and Mohamed (2010) and Olise (2010) are among several other studies that have expanded the literature of sustainable development within the framework of enhanced ICTs.

In general, the current study contributes to the aforementioned literature by providing a new evidence of the role of improved access to clean energy and technologies, technology innovation, and economic expansion in human development of the sub-Saharan African region. This study is unique because the direction of the study has sparsely been explored in the literature. Apart from the reviewed studies above, the determiants of human development such as the diffusion of ICT and demographic factors like gender composition and education level have only been examined in limited studies (Oladapo & Ab Rahman, 2016; Lee et al., 2017). Specifically, the study of Lee et al., 2017 employed economic freedom, civil liberties, and political rights as indicators for human development.

3. Data and Method

3.1 Description of dataset

We performed this study for the panel of 12 selected Sub-Saharan African countries (Benin, Botswana, Cameroon, Congo Republic, d'Ivoire Cote, Ethiopia, Ghana, Kenya, Mauritius, Nigeria, South Africa, and Zimbabwe) over the period of 2000-2016. Prior to embarking on the model description and estimation, the employed variables are described as follow:

- The Gross Domestic Product (GDP) is employed as a proxy for economic development or growth (measured in constant 2010 United States Dollars (USD).
- Human development Index (HDI) as a proxy for sustainable development. The variable is measured as an index.
- Access to clean energy and technologies for cooking (denoted as ACCESS-CE) is measured as the percentage of the total population with access to clean fuels and technologies.
- Access to technological innovation (denoted as ACCESS-TI). The proxy for this is access to mobile telephone (measured as the percentage of the total population with access to mobile communication.

The proxy employed for sustainable development in this study is the HDI, while the GDP proxy for economic growth and in this case it is employed to control for other unobserved variables. The Sustainable Energy for all of the World Bank (World Bank, 2019) is the source of access to clean energy and access to mobile telecommunication dataset. We retrieved the GDP series from the World Bank Development Indicator, WDI (World Bank Development Indicator, 2019). Also, we retrieved the HDI series from the United Nations Development Programme, UNDP (United Nations Development Programme, 2019).

Generally, we employed a balanced dataset. Consequently, Table 1 and Table 2 respectively presented the correlation matrix and the descriptive statistics for each country.

Table 1: Correlation matrix

SERIES	HDI	GDP	ACCESS-CE	ACCESS-TI
HDI	1.000			
GDP	0.175	1.000		
	(0.012)	-----		
ACCESS-CE	0.855	0.161	1.000	
	(0.000)	(0.022)	-----	
ACCESS-TI	0.713	0.217	0.505	1.000
	(0.000)	(0.002)	(0.000)	-----

Note: Here, we presents the correlation among the Human Development Index (HDI), Gross Domestic Product (GDP), population with access to clean energy technologies (ACCESS-CE), and population with access to technology innovation (ACCESS-CE).

Table 2: Statistical Properties of the variables

	HDI	Economic Growth	Access Clean Energy	Access to Technology
BENIN				
Mean	0.442	8.35E+09	4.116	34.238
Maximum	0.512	1.23E+10	6.440	96.230
Minimum	0.373	5.10E+09	1.830	0.018
Std. Dev.	0.046	2.21E+09	1.480	38.361
Skewness	-0.014	0.267	-0.042	0.503
Kurtosis	1.710	1.981	1.733	1.455
Jarque-Bera	1.526	1.213	1.141	3.115
BOTSWANA				
Mean	0.626	1.12E+10	55.141	67.121
Maximum	0.719	1.68E+10	64.080	163.875
Minimum	0.572	6.65E+09	45.120	0.000
Std. Dev.	0.054	3.24E+09	5.977	63.457
Skewness	0.55	0.362	-0.133	0.454
Kurtosis	1.735	1.888	1.830	1.551
Jarque-Bera	2.574	1.614	1.020	2.681
CAMEROON				
Mean	0.478	2.31E+10	16.081	27.521
Maximum	0.556	3.52E+10	23.040	78.229
Minimum	0.428	1.44E+10	9.880	0.021
Std. Dev.	0.041	6.14E+09	4.165	29.359
Skewness	0.482	0.380	0.121	0.639
Kurtosis	2.022	2.116	1.780	1.867
Jarque-Bera	1.730	1.246	1.095	2.673
CONGO REPUBLIC				
Mean	0.536	1.02E+10	16.186	43.590
Maximum	0.614	1.46E+10	24.130	108.894
Minimum	0.495	6.78E+09	10.000	0.000
Std. Dev.	0.040	2.65E+09	4.466	43.706
Skewness	0.789	0.374	0.269	0.406
Kurtosis	2.223	1.735	1.852	1.419
Jarque-Bera	2.706	1.888	1.124	2.763

	HDI	Economic Growth	Access To Electricity	Access To Technology
COTE d'lvoire				
Mean	0.429	2.34E+10	17.814	32.628
Maximum	0.478	3.12E+10	18.230	97.602
Minimum	0.397	1.91E+10	17.580	0.000
Std. Dev.	0.026	2.76E+09	0.176	36.338
Skewness	0.563	1.395	0.592	0.626
Kurtosis	1.938	4.887	2.868	1.693
Jarque-Bera	1.996	9.453*	1.007	2.731
ETHIOPIA				
Mean	0.347	2.39E+10	2.301	9.349
Maximum	0.460	5.33E+10	3.510	49.442
Minimum	0.201	1.05E+10	1.070	0.000
Std. Dev.	0.083	1.33E+10	0.814	15.119
Skewness	-0.256	0.870	-0.041	1.508
Kurtosis	1.791	2.487	1.648	3.966
Jarque-Bera	1.580	3.017	1.300	9.191
GHANA				
Mean	0.521	2.74E+10	12.690	42.134
Maximum	0.587	4.68E+10	21.710	134.489
Minimum	0.462	1.49E+10	5.890	47.905
Std. Dev.	0.042	1.08E+10	5.005	1.923
Skewness	0.271	0.599	0.326	0.681
Kurtosis	1.480	1.929	1.898	1.920
Jarque-Bera	2.388	2.366	1.160	2.770
KENYA				
Mean	0.496	3.48E+10	6.937	30.059
Maximum	0.568	5.54E+10	13.420	79.472
Minimum	0.446	2.36E+10	1.990	0.008
Std. Dev.	0.045	9.89E+09	3.394	31.387
Skewness	0.235	0.671	0.311	0.427
Kurtosis	1.470	2.193	1.781	1.476
Jarque-Bera	2.350	2.249	1.327	2.798

MAURITIUS				
Mean	0.717	8.49E+09	91.149	63.087
Maximum	0.790	1.24E+10	93.340	143.756
Minimum	0.649	5.11E+09	87.350	1.040
Std. Dev.	0.047	2.25E+09	1.922	49.290
Skewness	0.097	0.198	-0.756	0.215
Kurtosis	1.700	1.822	2.292	1.656
Jarque-Bera	1.585	1.415	1.975	1.824
NIGERIA				
Mean	0.422	2.82E+11	2.291	30.211
Maximum	0.528	4.64E+11	4.910	83.268
Minimum	0.213	1.46E+11	0.840	0.012
Std. Dev.	0.103	1.12E+11	1.276	32.390
Skewness	-0.797	0.309	0.684	0.482
Kurtosis	2.173	1.674	2.273	1.609
Jarque-Bera	2.958	1.961	1.700	2.625
SOUTH AFRICA				
Mean	0.648	3.29E+11	72.256	70.243
Maximum	0.702	4.20E+11	84.750	158.883
Minimum	0.610	2.33E+11	56.430	1.291
Std. Dev.	0.028	6.50E+10	8.997	54.518
Skewness	0.561	-0.012	-0.275	0.185
Kurtosis	2.214	1.508	1.850	1.601
Jarque-Bera	1.723	2.041	1.152	1.921
ZIMBABWE				
Mean	0.470	1.47E+10	30.895	31.128
Maximum	0.549	1.79E+10	32.400	102.118
Minimum	0.425	8.98E+09	29.050	0.000
Std. Dev.	0.040	2.87E+09	1.071	39.665
Skewness	0.797	-0.568	-0.176	0.815
Kurtosis	2.346	1.863	1.782	1.868
Jarque-Bera	2.721	2.367	1.139	3.613

Note: Human Development Index (HDI), Gross Domestic Product (GDP), population with access to clean energy technologies (ACCESS-CE), population with access to technology innovation (ACCESS-CE), and Std. Dev is the Standard Deviation.

3.2 Estimation framework

The drivers of inclusive human development have been consistently modelled from different framework (Asongu & Nwachukwu, 2016; Asongu & Le Roux, 2017; Lee et al (2017); Asongu & Odhiambo, 2019a; Asongu & Odhiambo, 2019b). İn the current context, model the drivers of sustainable development (HDI) such that access to clean energy technologies, access to technology innovation, and economic growth are all incorporated as follows:

$$HDI = f\,(GDP,\ ACCESS\text{-}CE,\ ACCESS\text{-}TI) \quad (1)$$

3.2.1 Estimation procedure

This first step toward examining the relations between the concern variables is by verifying the stationarity of the variables. Here, the stationarity tests employed are the Levin et al. (2002) and Im et al. (2003) unit root tests. Accordingly, the results of the unit root approaches are carefully illustrated in Table 3. Consequently, we examine the evidence of potential cointegration (long run) through the approaches of Kao (1999) and Pedroni (2004).

Table 3: The Unit Root and Cointegration Test

Unit Root Test	**LLC**		**Im, Pesaran Shin**	
	Level	Δ	Level	Δ
GDP	5.460	-1.932^{B}	8.863	-2.094^{B}
HDI	-1.099	-2.120^{B}	3.495	-2.132^{B}
ACCESS-CE	0.985	-0. 635	-3.075^{A}	-3.075^{A}
ACCESS-TI	-0.179	-3.687^{A}	3.828	-2.959^{C}

Note: Here, we presents the unit root tests result for Human Development Index (HDI), Gross Domestic Product (GDP), population with access to clean energy technologies (ACCESS-CE), and population with access to technology innovation (ACCESS-CE).

The choice of the study bloc in SSA provides this study justification for homogeneity in the sample selection given all countries investigated share same economic, political and demographic statistics and the modelling estimators (Kao and Pedroni cointegration techniques) supports the strong assumption as well as the study fail to find validation for cross-sectional dependency which could pose threat of common shock of heterogeneity. The evidence implied in Table 4 shows significant evidence of long-run relationship among HDI, GDP, ACCESS-CE, and ACCESS-TI.

Table 4: Kao and Pedroni Residual Cointegration Test

Kao Residual Cointegration Test (Panel A)

	T-statistic (p-value)
ADF =	-3.618 (0.000)

Pedroni Residual Cointegration Test (Panel B)

Alternative hypothesis: common AR coefs. (within-dimension)

	Statistic	Probability	Weighted Statistic	Probability
Panel v-Statistic	0.464	0.321	-0.336	0.632
Panel rho-Statistic	-0.088	0.465	0.497	0.690
Panel PP-Statistic	-4.565	0.000[A]	-2.712	0.003[A]
Panel ADF-Statistic	-5.454	0.000[A]	-4.217	0.000[A]

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Probability
Group rho-Statistic	2.529	0.994
Group PP-Statistic	-1.086	0.139
Group ADF-Statistic	-3.479	0.000[A]

Taking the evidence of stationarity and cointegration forward, the estimation of the model (equation 1) is performed but first by employing the logarithmic transformation of GDP in the model accordingly:

$$HDI_{it} = \beta_0 + \beta_1 LogGDP_{it} + \beta_2 ACCESS + CE_{it} + \beta_3 ACCESS + TI_{it} + \varepsilon_{it} \qquad (2)$$

where β_0 represents the constant term, and β_1, β_2, and β_3 are the respective coefficients that demonstrate the extent of relationship/impact between the dependent (HDI and the explanatory variables (GDP, ACCESS-CE, and ACCESS-TI), and ε_{it} represents the stochastic term.

Although the standard Autoregressive Distributed Lag (ARDL) is inadequate to control bias resulting from the mean-differenced autonomous factors and the disturbance term in a panel data, the ARDL-PMG approach of Pesaran et al. (1999) is rather a better option. In specific, the ARDL-PMG approach is considered suitable because of (i) it unique characteristic to example a mixed order of integration series, (ii) it provides both the long-run and short-run estimates concurrently, and that the approach is adequate in analyzing a dataset with a small number of observation. Thus, the PMG-ARDL approach for equation 2 is presented as:

$$\Delta HDI_{it} = \emptyset_i ECT_{it} + \sum_{j=0}^{q-1} \beta_{ij} \Delta X_{1(t-j)} + \sum_{j=1}^{p-1} \psi_{ij} \Delta HDI_{i(t-j)} + \varepsilon_{it} \quad (3)$$

$$ECT_{it} = HDI_{i(t-1)} - X_{it}\theta \quad (4)$$

where HDI is the dependent variable while X is the set of explanatory variables (GDP, ACCESS-CE, and ACCESS-TI). Additionally, the same number of slacks q is employed across singular cross-sections i (panel of 12 countries) in time t (2000 to 2016). The Δ, ϕ, and θ are respectively the difference operator, the adjustment coefficient, and the long term coefficient that produces the respective coefficients β and ψ. The ε is the error term. The long-and short-run impact with ARDL estimates are presented in Table 5. Moreover, the Granger causality investigation through the approach of Dumitrescu and Hurlin (2012) is employed to ascertain the inference of predictability among the concerned variables (see appendix A2).

Table 5: The long-and short-run impact with ARDL estimate

Panel A (With HDI) Variables	Short-run Coefficient	Long-run Coefficient
GDP	0.040^{B}	0.019^{A}
ACCESS-CE	-0.004	0.003^{A}
ACCESS-TI	0.0001	0.001^{A}
Adjustment Parameter	-0.18^{A}	
Panel B (Dignostic Tests)	**FMOLS**	**DOLS**
GDP	0.017^{A}	0.017^{A}
ACCESS-CE	0.003^{A}	0.002^{A}
ACCESS-TI	0.001^{A}	0.001^{A}
R-Squared = 0.797		

Note: ^{A} denote the statistical significance at 1%. The long-run relationship among the Human Development Index (HDI), Gross Domestic Product (GDP), population with access to clean energy technologies (ACCESS-CE), and population with access to technology innovation (ACCESS-CE).

Cross-section (Short-run) Panel C

Countries	GDP	ACCESS-CE	ACCESS-TI	ECT(-1)
Benin	0.082^{A}	0.003^{A}	$6.90E\text{-}06^{A}$	-0.166^{A}
Botswana	0.012^{A}	-0.003^{A}	$9.21E\text{-}05^{A}$	-0.393^{A}
Cameroon	0.089^{A}	-0.027^{A}	0.001^{A}	-0.592^{A}
Congo Rep	0.002^{A}	0.010^{A}	0.0001^{A}	-0.195^{A}
Cote d'lvoire	0.070^{A}	-0.0003^{A}	0.0001^{A}	-0.035^{A}
Ethiopia	0.087^{A}	0.0144^{A}	-0.0001^{A}	-0.035^{A}
Ghana	0.035^{A}	0.0001^{A}	0.0004^{A}	-
Kenya	0.076^{A}	0.003^{A}	0.0004^{A}	-0200^{A}
Mauritius	-0.033^{A}	0.003^{A}	0.0003^{A}	-0.242^{A}
Nigeria	-0.072^{A}	-0.020^{A}	-0.0001^{A}	-0.322^{A}
South Africa	0.047^{A}	-0.006^{A}	-0.0001^{A}	-0.107^{A}
Zimbabwe	0.079^{A}	-0.022^{A}	0.0002^{A}	-0.006^{A}

Note: ^{A} and ^{B} denote the statistical significance at 1% and 5% respectively. The long-run relationship among the Human Development Index (HDI), Gross Domestic Product (GDP), population with access to clean energy technologies (ACCESS-CE), and population with access to technology innovation (ACCESS-CE).

4. Results and Discussion

This section of the study proceeds to explore the statistical properties of the outlined variables. The preliminary steps before econometrics analysis under consideration to investigate the key drivers of sustainable development (HDI) for a selected panel of SSA countries. Table 1 presents the pairwise correlation analysis of the highlighted variables. We observe a statistical positive significant relationship between economic development (GDP) and sustainable development (HDI). This implies that robust economic growth activities will induce higher indices which reflect HDI. Additionally, access to clean energy shows a positive association with the sustainability of human development, that is, the region should be put more concerted efforts to her energy sector. Interestingly, access to energy also spurs economic growth which resonates the position of (EIA, 2018). Additionally, access to information and communication technology (ICT) shows a statistically significant relationship with HDI, GDP and access to energy. All these highlighted relationships show that access to ICT is a key indicator to spur economic growth, sustainable development as triggered by the energy sector. Furthermore, the basic summary statistics that comprises of the measure of central tendencies such as the averages, median, mode and range also offered useful inference.

This study also explores the measure of dispersion that is, mean deviation, standard deviation and also symmetric characteristics like Kurtosis among others. For Benin, the reported mean for HDI is 0.442 unit with a minimum of 0.373 to maximum of 0.512. Thepeakness shows light tails of 1.710. Access to ICT measured by mobile penetration in Benin shows the highest averages and maximum and minimum with light tails as reported by the Kurtosis. Interestingly all countries under investigation share similar properties with economic expansion and ICT ranking high on the statistics. This suggests that these indicators are key drivers for human development in the SSA region. However, the preliminary analysis is not sufficient to substantiate the positive claim highlighted. To this end, more econometrics analysis is explored to validate or refute the current position

Proceeding to the quest of underpining the determinant of sustainable development, we explore the unit root properties of the outlined variables. This is necessary to prevent spurious analysis in terms of modelling variables integrated of order 2 i.e. I(2). Our study presents the unit root properties in Table 3 as reported by Im, Pesaran Shin (2003) and Lin Levin and Chu (2002) unit root test approaches. The test result shows mix order but not I(2) as approved by a statistical threshold. Thus, with the current unit root status, we can proceed with the equilibrium properties (cointegration). This study uses a battery of tests to present a robustness and soundness of analysis. Additionally, we used Kao residual test in conjunction with ADF fisher and Pedroni test presented in Table 4. All these tests are in uniformity of confirmation of cointegration bond over the sampled period. This is insightful as these variables have long-run convergence with sustainable development.

Subsequently, we proceed to investigate the magnitude (coefficients) over the outlined variable. Simultaneously, both short and long-run relationship were examined. The fitted model is robust with an error correction term of 18% on an annual basis with the contribution of economic development, access to clean energy and access to ICT over the sampled period. Furthermore, we observed that both GDP growth and access to ICT spur sustainable development. Specifically, a 1% increase in GDP growth in the short-run translates to 0.040% increase in sustainable development at 5% statistical level. This result resonates the finding of Asongu (2018) which coincide with the elaborate advocacy of the UN-SDG-8. Additionally, the positive effect of GDP growth on HDI also spilled-over to the ICT sector where access to ICT increases sustainable development The plausible explanation for the ICT-induce sustainable development position is due to the efficiency gained from conducting economic activities which increases productivity and thus translate into sustainable development. Supporting this claim, Lee et al

(2017) emplored the case of 102 countries between 2000 and 2013 and revealed thst ICT diffussion is a key determinant of humand development globally. Morover, the study mentioned that income level in each country and the type of technology avaliability iu the countries moderates the impact of ICT on human development. This position is also been strengthen by the spillover effect of ICT development in the region given the region is deficient in ICT infrastructure (Asongu & Roux, 2017).

Concerning the role of clean enegry, the long run impact of access to clean energy on human development is significant and positive. By economic intuition this is correct because the use of clean energy reduce environmental hazard that would have jeopardized human development in the process of economic activities. This ascertion is supported by the work of Lee et al (2017). Specifically, Lee et al (2017) inferred that the level of household well-being is improved by the adoption of clean energy becasue clean energy is linked with education, assets, inclome level, and government subsidies. However, in the short-run, access to clean energy which is in line with the pursuit of UN-SDG-7 hinders HDI as reported in the PMG-ARDL regression. This reflects the current position of many countries in the examined SSA region which is plagued with huge energy deficit with little or no electrification (Samu et al., 2019). Additionally, the composition of clean energy in most of the examined countries are moslty hydro and biofuels which are not absolutely free from environmental demerits against clean technologes like wind and solar. The narrative is different in the long-run given the time to increase the share of clean technologies arising from energy financing from public-private partnership, thus causing a substantial increase sustainable development (EIA, 2018).

The EIA illustrated that energy is a key driver for long term economic and sustainable development. Thus, validating the energy-led growth hypothesis in the region (Alola, 2019). For the soundness of analysis robustness test of FMOLS and DOLS presented in panel B in Table 5 validated the ICT, energy and GDP growth induced growth in both short and long-run.

Additionally, on a country-specific analysis, all countries demonstrated convergence with statistical negative error correction term (ECT) affirming convergence over the outlined variables. The country-specific analysis for short-run dynamics reported in Table 5 in Panel C is very similar to previous tests.

On the level of predictability analysis, we leverage on the Dumitrescu Hurlin Panel Causality test to illustrates the Granger causality direction among the study variables as seen in the appendix section (Table A2). We observed a feedback Granger causality relationship between GDP and HDI, thus suggesting that both economic growth and HDI Granger causes each other in SSA. Similarly, access to clean energy and HDI exhibits two-way causality relationship between each other. These outcomes suggest that historical information of GDP growth and clean energy are a good predictor for sustainable development and vice versa. This outcome aligns with (Asongu & Roux, 2017; Asongu et al., 2018). Additionally, uni-direction Granger causality is seen between clean energy and GDP growth, HDI and access to IT, and clean energy and access and IT. These outcomes are very insightful and revealing in the context of SSA bloc. Conclusively we can validate the assertion that access to clean energy, access to ICT are key drivers of sustainable development that translate into higher income level, higher illiteracy rate which reflects in citizenry life expectancy in the region.

5. Conclusion and Policy suggestions

The United States Energy Information Administration (EIA, 2018) highlighted that a country economic growth and her energy consumption are connected. However, the rising energy demand across the globe has not matched its requisite supply which has left huge deficit among household and aggregate level as well. This occurrence has drawn the attention of government officials in both developing and developed economies. This energy deficit also identified as energy poverty especially at the micro-level with household not been able to meet her energy demand (Thomson et al., 2016). In lieu of the above highlights, the extant energy literature has received little empirical entries been recorded for sub-Saharan African blocs. To achieve this, this study examines with new perspectives key catalyst of sustainable development via human development in a balanced panel framework. The choice of the variables is in accordance with the UN-SDGs to rationalise the claims outlined in this study. The result of Kao residual cointegration test alongside ADF fisher and Pedroni cointegration test are in harmony affirms the existence of a long-run bond between the variables under consideration. This is insightful for as these variables can trigger sustainable growth.

Our study regression analysis validates that sustainable development is induced by economic development in SSA. It means that increased economic activities spur higher and desirable HDI indices in the region in the short and long run. This is suggestive to the officials of the region to improve macroeconomic indicators in order to improve economic productivity in the region given the aftermath of higher HDI performance. Furthermore, statistical claim exists for the positive linkage between access to information technology and sustainable development in SSA region. The plausible and intuitive explanation for this connection between IT access and sustainable development is linked to technological advantage as outlined in the Solow growth model (SGM) which posits the pertinent role of technological efficiency to trigger ease of running business activities in the blocs at both micro-level (SME) and aggregate level and its spillover effect to other economic sectors through the channel of productivity.

On the other hand, in Sub-saharan African region, access to clean and responsible energy for all does not engender sustainable development which reflects the current situation in the bloc. In reality, most countries in the region have energy deficit in term of less energy for cooking and household activities and powering home appliances and spillover to HDI indices in term of literacy rate, life expectancy and income level. As previously outlined by the US Energy Information and Administration, energy access is believed to be a key to a nation's prosperity.

Our study shows that in the short-run access to energy has impeded the economic development in the region while in the short run a positive relationship is seen between energy access and economic growth. However, the positive growth is very minimal as most countries are still at the very beginning of their strives to improve the economy through access to clean energy.

Given the outcomes from this study the following concluding remarks and policy inferences are presented below:

5.1 Policy

The statistical positive nexus seen between economic development proxy by GDP and HDI presents a suggestive policy to administrators in SSA bloc. This implies that robust economic structure will spur higher literacy rate increase income level which translates into increased life expectancy. Thus, the need to explore a favourable climate for sustainable development should be pursued in the region. Enhanced access to Information and communication technology (ICT) via technological innovation also shows strength to drive sustainable development in SSA region. Given this connection, government need to reinforce the need for the development of technological infrastructure in the region through partneship with private institutions and by providing enabling total environment for foreign direct investment in the area of ICT.

This study also gave credence to the energy-induced sustainable development (SD) growth hypothesis. This implies that energy is a key determinant for SD in the SSA region. This is possible through the channel of access to clean electrification. However, the region is plagued with huge electricity deficit or load shedding in the region which has spillover effect on other sectors of the economy like manufacturing, service and even the small Medium enterprise to stir economic activities and by extension sustainable development in the region. Although most countries are on the trajectory of changing the ills of energy poverty, however, there is a need for more strides to foster more growth in the region. Therefore, there is a need for policymakers to pursue policies that increase clean and affordable access to energy (SDGs-7) such as providing energy subsidies to energy companies to encourage more production that gurantees cheap and availability of energy technologies. Additionally, the administrators need to involve public-private participation in order to expand energy financing as well as promoting policy that encourgares foreign direct investment. By improving on the countries international reputation through taking decisive steps toward reduction of curruption and financial recklessness, the African countries could be positioned to recieve project financing from international institutions such as the World Ban and United Nations affiliated organizations.

5.2 Recommendation for future studies

Moreover, this study explored the key drivers of sustainable development in Sub-Saharan Africa by offering a new perspective to the extant literature which has received less documentation on them by considering the moderating role of access to clean energy and access to technological innovation to the debate. However, as a direction for other studies to advance the literature, there is a need to explore the theme by accounting for a demographical indicator like population, political regime. Furthermore, there is need to investigate the drivers for sustainable development by using microstate or disaggregated data for other developing, or emerging blocs like the Middle East and North Africa and Latin America (MENA), the Caribbean and even other blocs within the African continents. Such investigation will extent the literature.

Conflicts of Interest: The authors declare no conflict of interest.

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APPENDIX

Table A1: The Sustainable Development Index (SDI) of selected African countries

Country	Sustainable Development Index (SDI)
Benin	0.547
Botswana	0.351
Cameroon	0.590
Congo Republic	0.479
d'Ivoire Cote	0.515
Ethiopia	0.486
Ghana	0.630
Kenya	0.623
Mauritius	0.615
Nigeria	0.568
South Africa	0.675
Zimbabwe	0.569

Table A2: Dumitrescu Hurlin Panel Causality Test

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
GDP ⇏HDI	6.350[A]	4.132	4.E-05
HDI ⇏GDP	4.324[C]	1.959	0.050
ACCESS-CE ⇏HDI	5.473[A]	3.191	0.001
HDI ⇏ACCESS-CE	5.223[A]	2.922	0.004
ACCESSM-⇏HDI	4.027	1.639	0.101
HDI ⇏ACCESS-TI	4.622[B]	2.277	0.023
ACCESS-CE ⇏GDP	6.095[A]	3.858	0.000
GDP ⇏ACCESS-CE	2.744	0.262	0.793
ACCESS-TI ⇏GDP	2.371	-0.138	0.890
GDP ⇏ACCESS-TI	3.080	0.622	0.534
ACCESS-TI ⇏ACCESS-CE	3.771	1.364	0.173
ACCESS-CE ⇏ACCESS-TI	4.868[B]	2.542	0.011

Note: [A], [B], and [C] denote the statistical significance at 1%, 5% and 10% respectively. The long-run relationship among the Human Development Index (HDI), Gross Domestic Product (GDP), population with access to clean energy technologies (ACCESS-CE), and population with access to technology innovation (ACCESS-CE). Here also ⇏ denotes " does not Granger cause"