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The anthropogenic consequences of energy consumption in Sub-Saharan Africa: Is there a role for education?

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ABSTRACT

Sub-Saharan Africa has been one of the most affected regions in the world by the emissions-induced climate crisis. Even though the region is not the biggest emitter of CO_2 globally it is important to understand the dynamics of emissions in the sub-continent. This study takes a look at one of those determinants –education. Specifically, the study attempts to unravel the role of education on $C0_2$ emissions in Sub-Saharan Africa. To achieve this aim, the study adopts a sample of 46 countries in the region and employs data covering the period 1996–2018. The estimations are carried out using four estimators (Pooled OLS, Fixed Effects, Random Effects and System-GMM). The findings of the study reveal that the improvement in education has two different impacts on $C0_2$ emissions in Sub-Saharan Africa. On one hand, the Pooled OLS reveal a negative relationship between education and emissions – (0.000374%) while the random Effects and system GMM reveal a positive relationship between education and $C0_2$ emissions (0.000934% & 0.000233% in the region. Similarly, energy consumption is positively associated with carbon emissions (0.0209%). More so, the study suggests that efforts be made to improve education with an emphasis on the harmful effects of emissions to the environment as this will aid to reduce emission-related activities in Sub-Saharan Africa.

1. Introduction

Sub-Saharan Africa is a continent that is so endowed with both human and natural resources which can be translated into sustainable development if properly harnessed. The region is the world's largest free-trade zone with a population of roughly 1.2 billion people. The region also comprises of low, lower-middle and high-income countries and 20 of them are devastated by insecurity (World Bank, 2021). In 2018, East Africa led the region by 5.7% GDP growth, North Africa recorded 4.9%, West Africa recorded 3.3%, Central Africa recorded 2.2% while Southern Africa recorded 1.2%. More so, that growth pattern lingered till 2019 where East Africa maintained robust growth of 5.9% (African Development Bank, 2019). East and Southern Africa comprises 26 countries with a population of roughly 700 people and a GDP of $945,567 million. South Africa, an upper-middle country is the largest economy in this sub-region. Angola, Kenya and Ethiopia follow suit whereas the only high-income countries are Mauritius and Seychelles. The Western and Central Africa comprises 22 countries and accommodates roughly half a billion people. These sub-regions are rich in natural resources and have a GDP of $711 million. Nigeria, Gabon and the Republic of Congo are oil producers, Ghana and Cote' d'Ivoire export Cocoa while Benin and Burkina Faso export Cotton (world bank, 2020).

Both developed and developing economies in the world strive to achieve a high economic prosperity and sustainable development. The achievement of this objective appears to be difficult due to the threat of environmental challenges as characterized by global warming and climates changes. More so, economies consume much fossil fuels to increase productivity and trade, thereby meeting their growth targets. There is a rise in carbon dioxide emission due to the high energy consumption globally and that in turn results in more environmental pollution. Droughts, floods and rising sea levels are all the manifestations of climate changes that are caused by the increased consumption of fossil fuels over some decades. In the long run environmental quality worsens as economic growth, capital and environmental politics improve but it gets better with increased renewable energy use (Khan et al., 2021).

As population, urbanization and pursuit of economic growth intensify, the world's energy demands rises and that poses threat to our environmental wellbeing. (Razmi et al., 2020) established that clean energy technology becomes more prominent as a result of the environmental damages which are caused by the consumption of fossil fuels. In the 2000's about 40% of the entire global energy produced was consumed by Europe and North America while Asian developing economies

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consumed about 20%. That was also envisaged to worsen in 2040 (Vural, 2020). A third of the world's energy was consumed by some developing economies such as China, Brazil, India, Indonesia, South Africa and Mexico and that was predicted to rise to 40%. Although we begin to see a substantial shift to renewable energy consumption, the world still needs to explore renewable energy resources and make renewable energy technology cheaper especially in the developing countries.

(Grossman and Krueger, 1991) wrote a seminal paper that maidenly analysed the link between GDP per capita and environmental damage through the environmental Kuznets curve hypothesis. Onward, we saw a continual interest by researchers in the field of environmental economics to examine the environmental Kuznets curve hypothesis. While some studies found evidence to validate the inverted U-shaped Kuznets curve hypothesis [see (Atasoy, 2017; Bilgili et al., 2016; Dong et al., 2017, 2018; Narayan and Narayan, 2010). Other studies found the opposite or different evidence of the curve [see (Akpan and Abang, 2014; Endeg, 2015)]. Meanwhile, several researchers have doubted the validity of the income parameters and yet there have been fresh attempts to upgrade the validity of the estimates by using more befitting variables such as income inequality and energy utilization's indicators. There is also a recent attempt to introduce education parameters into the model to avoid a misspecification error based on the evidence that education and income coefficients strongly correlate [as cited in (Balaguer and Cantavella, 2018)]. (Gong et al., 2017; Musakwa, 2017; Sumari et al., 2019; Woldai, 2020) have all in their different studies highlighted the connection between education through space-based information and environmental sustainability.

It is clearly evident in the literature that many studies which sought to assess the link between energy use and environmental degradation as either regional or country-specific studies. These studies used different analytical tools and their conclusions have never been consistent ((Balsalobre-Lorente et al., 2017; Boluk and Mert, 2014a; Jebli and Youssef, 2017; Udi et al., 2020)Udi et al., 2020; Balsalobre-Lorente et al., 2017; Jebli and Youssef, 2017; Boluk and Mert, 2014). On the other hand, we know very limited attempts to examine the empirical verification of the almighty environmental Kuznets curve hypothesis through the role of education and one of the most recent studies was (Balaguer and Cantavella, 2018). Furthermore, we do not know of any new attempts to merge the two seemingly related but distinct studies as one study specifically for Sub-Saharan Africa as a case study. Indeed, this study uniquely stands out as one of the recent few attempts to analyse the role of education in the environmental Kuznets curve theory and indeed the first to examine the role of education in the energy-growth-environment discourse for Sub-Saharan Africa.

This study contributes to the literature by furnishing us with an empirical investigation of Sub-Saharan African countries and assessing the role of Education in the emissions-energy consumption-growth discourse for Sub-Saharan Africa. The study adds ideas to the rich literature on the two different studies; energy use – environmental pollution study on one hand and the other hand the study on economic growth – environmental pollution link. Furthermore, the study applied both static and dynamic models to come up with robust findings. Fixed effects and Random effects models were used to identify panels heterogeneities which the Pooled OLS could not identify. While the study adopted the system generalized method of moment (system-GMM) as a dynamic model.

This unique study answers the following questions empirically: (1) Does education play any significant role in verifying the almighty environmental Kuznets curve (EKC) theory? (2) Is the environmental Kuznets curve theory valid for Sub-Saharan Africa? (3) what is the effect of energy consumption on environmental degradation? Nonetheless, the apriori expectations are; education plays role in mitigating the adverse effect of environmental pollution while the EKC hypothesis is valid for Sub-Saharan Africa. Moreover, energy use significantly contributes to economic growth in the region.

The study is structured into the following parts: Part 2 sheds lights on the existing empirical literature while part 3 exposes the model applied and it explains why it is appropriate for the study. As Part 4 contains results presentations and discussions, part 5 presents the summary and recommendations.

2. Literature review

An extensive literature review was conducted to better understand the problem. Several past studies were carefully read and assessed. Given this, we categorized our review into two; on one hand literature on education and energy use-environment nexus while on the other hand literature on energy use and economic growth were reviewed.

2.1. Education and energy consumption-environmental nexus

Since the maiden study on the impact of economic growth on environmental pollution which (Grossman and Krueger, 1991) championed, studies on that relationship began to flow into the literature. (Grossman and Krueger, 1991) empirically proved that economic growth affects environmental pollution at different stages and that the relationship takes a U-shaped dimension. These findings were coined to be the popular environmental Kuznets curve (EKC) hypothesis. Consequently, studies were conducted for different countries and regions to test the validity of the said hypothesis and whose results were found to be inconsistent.

Several studies conducted found that in the long run, economic growth ameliorates environmental quality and that affirms the EKC hypothesis (Adedoyin et al., 2020; Apergis, 2016; Balaguer and Cantavella, 2018; Gyamfi et al., 2021; Khan et al., 2021; Sapkota and Bastola, 2017; Umaroah, 2019). The affirmation of the EKC hypothesis was equally done by many studies based on countries and regions. As a country-specific study, it was affirmed for the United States by Atasoy (2017), while at the regional level, Baloch et al (2020) validated it in their study that considered organization for economic cooperation and development countries (OECD). Nevertheless, as (Bilgili et al., 2016) confirmed for developed countries in their study which incorporated the organization for economic cooperation and development (OECD) states, Apergis (2010) also settled for the same position for ASIAN and commonwealth of independent states.

However, numerous studies which failed to affirm the almighty EKC hypothesis. Some of these studies had rather found an inverted *U*-shaped scenario as against the validated *U*-shaped curve (Bello and Abimbola, 2010; Chuanqi and Xiaojun, 2013; Mahmood and Shahab, 2014). Recent attempts to test the validity of the EKC hypothesis had tried to incorporate some befitting variables such as income inequality and urbanization into the adopted model most intentionally to enhance the estimation of the results estimation (Shahbaz et al., 2015 R 2.2). The argument that the quality of human capital signals about the environmental status prompted some researchers to consider including education in the model (Umaroah, 2019). Barro (2001) stressed on the fact that education and income are purportedly greatly correlated and so it is seen as an attempt to do away with reasonable bias on income coefficients.

Although there have not been numerous studies on the role of education in mitigating environmental degradation, the results produced by these studies have not been consistent with one another. Williamson (2017) proved that education does not in any way improve environmental quality and that the EKC hypothesis does not exist when the human capital indicator (education) is considered in the model. Sapkota and Bastola (2017) found combined results of both validation and invalidation of the EKC hypothesis via the role of education, in the study conducted by (Umaroah, 2019) education mollifies the environmental pollutants and normal U-shaped curve exists only in the short run. On the contrary, (Balaguer and Cantavella, 2018) discovered that education improves environmental quality and an inverted *U*-shaped curve exists for Australia.

It is very much clear that the findings of previous researches as highlighted above had failed to produce a common ground or positions. Indeed, these findings were contradicting and inconsistent with one another. However, our study proposes that education ameliorates environmental quality while confirming the existence of the EKC hypothesis for the Sub-Saharan Africa. So, we hypothesise that education relates negatively to carbon emission while the EKC hypothesis exists for Sub-Saharan Africa.

2.2. Energy consumption and economic growth

In the last decade, the discourse on the nexus between energy consumption, economic growth as well as its environmental damages has attracted a significant amount of attention in the literature ((Adedoyin et al., 2020; Khan et al., 2021; Khan and Hou, 2021; Tawiah et al., 2021; Udi et al., 2020)Khan et al., 2021; Khan and Hou, 2021; Tawiah et al., 2021; Adedoyin et al., 2020; Udi et al., 2020).

Using the generalized least square (GLS) method to study the nexus between energy consumption and economic growth for Bangladesh from 1981-2017, (Sarker et al., 2019)Sarker et al. (2019) found a positive relationship between energy consumption (both renewable and non-renewable) and economic growth. A similar study was carried out for Economic Co-operation and Development (OECD) countries and findings reveal that both renewable and non-renewable energy use stimulates economic growth (Shahbaz et al. 2020). Bozkurt and Arik ((Boluk and Mert, 2014a)Boluk and Mert, 2014) adopted the ARDL model to analyse the link between energy use and environmental quality for the OECD countries over the period of 1980–2012. Their findings suggest that clean energy use adversely affect GDP for developing economies while it positively affects GDP for developed countries.

Usman et al. (2020) examined how environmental damage is affected by renewable energy use, economic growth, trade policy and biocapacity in the United States (US) through the autoregressive distributed lag (ARDL) model from 1985Q1 to 2014Q4. They found a negative connection between renewable energy use and ecological footprints while economic growth and biocapacity positively affect the ecological footprint. Hence, environmental degradation is negatively linked to renewable energy. Similarly, Majeed and Luni (2019) used a panel data of 166 countries to discover any connections between renewable energy use, water withdrawal and environmental degradation from 1990 to 2017. Their findings proved useful link between renewable energy use and environmental degradation as the former significantly mitigates the latter. Contrarily, water withdrawal was found to increase emission level. Furthermore, the useful link between renewable energy use and environmental degradation was also affirmed by Balsalobre-Lorente et al. (2017) who attempted to investigate the expected link between renewable energy use and carbon emission in Spain and United Kingdom from 1985 to 2016. Their findings suggest that electrical energy in renewables, energy innovation and abundance of natural resources exert negative influence on the environment.

Previous literatures on the nexus between energy use (both renewable and non-renewable) and economic growth produced mixed results. We propose for our study that energy consumption enhances economic growth. Given this, we hypothesise that energy consumption has a positive relationship with economic growth for the Sub-Saharan Africa.

2.3. Literature gap and motivation

The Sub-Sahran African countries, unfortunately lack workable institutions that could support the present global efforts of enforcing environmental protection policies. The obvious reality that Sub-Saharan Africa relatively emits less emission caused its absence in the world's scene for environmental protection measures. Indeed, there are significant concerns and needs for these countries to enforce global environmental regulations (Tawiah et al., 2021). However, the fact that Sub-Saharan African emits fewer emissions does not exonerate it from the effect of environmental pollution and the absence of workable institutions to enforce environmental protection policies make the situation even worst.

There are few pieces of literature that sought to explore the role of education in mitigating environmental pollution (Balaguer and Cantavella, 2018; Sapkota and Bastola, 2017; Umaroah, 2019). However, despite our thorough investigations, we still could not find any study which examined the role of education in the emissions-energy consumption-growth discourse for Sub-Saharan Africa. This appears to be a fresher and newer study paying more attention to Sub-Saharan Africa and adopting a more robust methodology.

Table 1
Description of variables.

Variable	Description	Source
LC02	Carbon dioxide emissions (metric tons per capita)	The World Bank
LGDP	Gross Domestic Product, billions of 2010 U.S. dollars	The World Bank
LGDP2	Square of Gross Domestic Product, billions of 2010 U.S. dollars	Computed by Authors
LGDP3	Cube of Gross Domestic Product, billions of 2010 U.S. dollars	Computed by Authors
EDUC	School enrollment, primary (% gross)	The World Bank
LENC	Energy use (kg of oil equivalent per capita	The World Bank

Table 2
Summary statistics.

Variable	Observation	Mean	Standard deviation	Minimum	Maximum
LC02	1,058	4.760333	2.37401	0	6.77079
LGDP	1,058	5.574278	1.66882	0	6.904751
LGDP2	1,058	33.8549	12.77046	0	47.67558
LGDP3	1,058	209.1979	94.48879	0	329.188
EDUC	1,058	341.242	277.0767	1	849
LENC	1,081	2.232633	2.635519	0	6.148468

Table 3
Correlation matrix.

	LC02	LGDP	LGDP2	LGDP3	EDUC	LENC
LC02	1					
LGDP	0.0830*	1				
	0.0069					
LGDP2	0.0897*	0.9620*	1			
	0.0035	0				
LGDP3	0.0932*	0.9075*	0.9869*	1		
	0.0024	0	0			
EDUC	0.0239	0.0542	0.0533	0.0507	1	
	0.4374	0.0783	0.0831	0.0991		
LENC	0.0355	-0.0252	-0.0112	-0.0016	0.0494	1
	0.2484	0.4128	0.7167	0.9575	0.108	

3. Data and methodology

3.1. Data and variable description

In an attempt to estimate the model, data ware collected for selected variables over the period 1996 to 2018. The major source of data was from the World Bank Development Indicators. for instance, for C02 emissions we used data on Carbon dioxide emissions (metric tons per capita); for economic growth we used Gross Domestic Product, (billions of 2010 U.S. dollars), the square and cube of economic growth were computed by the authors, while for education data on primary school

Table 4
Pooled OLS (or LSDV) for comparative analysis across the 4 sub-regions in Sub-Saharan Africa. Dependent variable: LCO2.

	East Africa	Central Africa	West Africa	Southern Africa
LGDP	0.859**	0.537	-0.654**	-0.728**
	(0.373)	(0.418)	(0.257)	(0.290)
LGDP2	-0.318**	-0.234	0.280***	0.214***
	(0.129)	(0.146)	(0.0881)	(0.0808)
LGDP3	0.0298**	0.0207	-0.0271***	-0.0178***
	(0.0116)	(0.0132)	(0.00756)	(0.00656)
EDUC	-0.000391	-0.000910***	8.35e-05	-0.000414***
	(0.000290)	(0.000331)	(7.38e-05)	(0.000153)
LENC	0.0168	0.101***	-0.00790	0.0107
	(0.0277)	(0.0369)	(0.00997)	(0.0110)
Year Dummies	Yes	Yes	Yes	Yes
Observations	276	207	345	230
R-squared	0.802	0.755	0.958	0.974

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

enrollment (% gross) was used and for Energy Consumption we used data on Energy use (Kg of Oil equivalent per capita).

3.2. Model and method

To estimate the impact of education and $C0_2$ emissions in Sub-Saharan Africa, we specify the following model equation.:

$$LCO_2 = f(LGDP, LGDP2, LGDP3, EDUC, LENC) \quad (1)$$

$$LC0_{2it} = \beta_0 + \beta_1 LGDP_{it} + \beta_2 LGDP2_{it} + \beta_3 LGDP3_{it} + \beta_4 EDUC_{it} + \beta_5 LENC_{it} + \mu_{it} \quad (2)$$

Where; *LC02, LGDP, LGDP2, LGDP3, EDUC, LENC* = value of the series; μ_t = Error term; and β_i = the parameter for estimation. This study makes use of data from 46 countries in Sub-Saharan Africa covering the period 1996 to 2018. To make the study more interesting: (1) we split the panel into four regions in Sub-Saharan Africa namely; West Africa, East Africa, Southern Africa and Central Africa. Secondly, we employ the use of static and dynamic models to see the outcome of the education-emissions relationship from varying econometric methods. The static models used include the pooled ordinary least squares (POLS) which are unable to recognize heterogeneities across panels and the Fixed effects (FE) and Random Effects (RE) estimators which can recognize panel heterogeneities. We also use the system generalized method of moments (sys-GMM) as a dynamic model estimator, which has been known to yield a reliable and consistent result.

4. Results and discussions

4.1. Pre-estimation diagnostics: Descriptive statistics and correlation

According to the descriptive statistics presented in Table 2, it can be seen that GDP has the highest average value and single maximum value. On the other hand, energy consumption is the most dispersed variable in the model. Table 3 presents the correlation matrix which reveals a positive relationship between the control variables LGDP, LGDP2, LGDP3, EDUC, LENC and the dependent variable LC02.

4.2. Estimation: Main results

According to the results presented in Table 4 for the sub-regions, we find that the model is consistent and significant. Given that the coefficient for LGDP. LGDPsquare and LDDPcube are positive, negative and then positive in East Africa, we conclude that there is an N-shaped Environmental Kuznets curve in the region. This means that while economic

Table 5
Fixed effects and random effects for comparative analysis across the 4 sub-regions in Sub-Saharan Africa. Dependent variable: LCO2.

	Fixed effects				Random effects			
	East Africa	Central Africa	West Africa	Southern Africa	East Africa	Central Africa	West Africa	Southern Africa
LGDP	1.598	0.0358	0.0405	-0.175	1.360	0.0620	0.0218	-0.182
	(0.958)	(0.863)	(0.417)	(0.402)	(1.000)	(0.825)	(0.422)	(0.400)
LGDP2	-0.337	-0.00519	0.0144	0.0609	-0.285	-0.0173	0.0211	0.0628
	(0.315)	(0.316)	(0.145)	(0.127)	(0.316)	(0.304)	(0.147)	(0.126)
LGDP3	0.0235	-0.000387	-0.00267	-0.00558	0.0198	0.000764	-0.00328	-0.00573
	(0.0274)	(0.0290)	(0.0128)	(0.0111)	(0.0272)	(0.0281)	(0.0130)	(0.0111)
EDUC	-0.000182	-0.000172	0.000101	3.05e-05	-0.000233	-0.000216	0.000100	2.42e-05
	(0.000232)	(0.000232)	(7.36e-05)	(7.63e-05)	(0.000224)	(0.000212)	(7.24e-05)	(7.79e-05)
LENC	0.00117	0.0171	-0.00354	0.00285	0.00234	0.0203	-0.00364	0.00289
	(0.0136)	(0.0260)	(0.00252)	(0.00204)	(0.0137)	(0.0258)	(0.00250)	(0.00208)
Constant	3.298***	5.407***	5.645***	6.348***	3.598***	5.435***	5.649***	6.357***
	(0.516)	(0.321)	(0.116)	(0.238)	(0.896)	(0.566)	(0.181)	(0.237)
Year Dummies	Yes	Yes	Yes	Yes	Year	Yes	Yes	Yes
Observations	276	207	345	230	276	207	345	230
R-squared	0.917	0.915	0.988	0.994				

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1Table 6 presents results for the estimation of CO_2 emissions for the full sample. The estimations are carried out using four estimators (Pooled OLS, Fixed Effects, Random Effects and System-GMM). The model appears to be consistent with previous studies howbeit at various levels of significance. Results illustrate that there is a positive and negative relationship between economic growth (LGDP, LGDP2, and LGDP3) and emissions but the relationship is statistically insignificant. On the other hand, education has two different impacts on $C0_2$ emissions in Sub-Saharan Africa. On one hand, there is a negative relationship (at a 1 % level of significance) between educational rate and emissions in the region as shown by the coefficient of 0.000374. This entails that an improvement in the number of educated persons in the region will reduce the level of emissions in the region by an average of 0.000374 %. An educated population will stand a better chance to understand the harmful effects of emissions on the environment hence they are more likely to use more non-carbon emitting energy resources. This finding is similar to that of (Managi and Jena, 2008). On the other hand, the rate of education has a positive impact on emissions in Sub-Saharan Africa. This means that as the number of educated people increases in the region emissions go up. Studies by (Gangadharan and Valenzuela, 2001; Hill and Magnani, 2002) agree with this. Considering the mixed nature of the relationship between education and emissions, the result obtained by this study conform to that of (Sapkota and Bastola, 2017). Similarly, energy consumption is associated with an increase in emissions by 0.0209 % at a 10 % level of significance. This result is according to expectation and could be due to the popular use of combustible energy to meet increasing energy demand in the region. These findings are similar to that of (Sebri and Ben-Salha, 2014; Wang, 2018).

Table 6
Pooled OLS, fixed effects, random effects and system-GMM estimation results for the full sample.

	Pooled OLS	Random effects	Random effects	One step GMM
L.LC02				0.934***
				(0.00522)
L2.LC02				-0.00748
				(0.00494)
LGDP	0.206	1.961	0.803	0.174
	(0.196)	(1.927)	(1.224)	(0.254)
LGDP2	-0.0582	-0.583	-0.279	-0.0687
	(0.0586)	(0.586)	(0.407)	(0.0882)
LGDP3	0.00465	0.0508	0.0269	0.00693
	(0.00499)	(0.0506)	(0.0363)	(0.00790)
EDUC	-0.000374***	0.000934*	0.000598	0.000233*
	(0.000111)	(0.000544)	(0.000446)	(0.000139)
LENC	0.0209*	0.0233	0.0274	0.0103
	(0.0107)	(0.0302)	(0.0294)	(0.0157)
Year Dummies	Yes	Yes	Yes	Yes
Constant	5.259***	2.549	3.506***	-0.109
	(0.226)	(1.820)	(0.881)	(0.127)
Observations	1,058	1,058	1,058	966
R-squared	0.872	0.025		
Number of Country ID		46	46	46
Post-Estimation Diagnostics				
Hausman P value		0.000		
AR 2 P-value				0.208
Sargan				0.000
Hansen				1.000

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

expansion leads to high emissions in the early stage of development in the region, emissions decrease with increasing economic activities in the following stage and begin to rise afterward. Economic expansion has no impact on emissions in the Central Africa region. While for West and Southern Africa the relationship between economic expansion and emissions takes an inverted *N*-shape as emissions fall in the earlier stage of economic expansion, increase in the following stage and begin to fall again.

There is a negative relationship between education and emissions in Central and Southern Africa regions. This means that as the rate of education increase, emissions fall. However, there is no significant relationship between education and emissions in East and West Africa. On the other hand, energy consumption in Central Africa will lead to an increase in emissions. This result is as expected, given that energy consumption in this region comprises of the use of carbon-emitting energy sources. Energy consumption has no impact on emissions in the other three regions.

In Table 5, the fixed effects and random effects estimations results for the sub-regions show that there is no significant relationship between Economic expansion, education, energy consumption, and $C0_2$ emissions in any of the regions (East, Central, West and Southern Africa).

5. Conclusion

The present world experiences population explosion, urbanization and ceaseless pursuit of economic growth which raise energy exploration, energy demand and consumption globally. This rise in energy consumption causes global warming and climate changes which are the most pressing environmental challenges manifesting in drought, flooding and rising sea level.

As part of efforts to reduce emissions around the globe, this study aims to examine the role of education on $C0_2$ emissions for 46 countries in Sub-Saharan Africa using data covering the period 1996–2018. Although there a numerous studies which investigated the energy-growth-emissions nexus for Sub-Saharan Africa and the world at large, none examined the role of education in mitigating environmental damages. To achieve our objective, a range of econometric techniques such as the Pooled OLS, Fixed Effects, Random Effects and System-GMM estimators were used to estimate both static and dynamic economic models. Given the study's apriori expectations, the study achieved its objectives. The study is novel based on its analytical approach and by considering education as one of the important variables affecting environmental damages. More so, the study improves on similar previous studies such as Umaroah (2019), Balaguer and Cantavella (2018) and Sapkota and Bastola (2017).

The findings of the study are quite interesting. On one hand, the Pooled OLS revealed a negative relationship between education and emissions, while the random Effects and system GMM revealed a positive relationship between education and $C0_2$ emissions in the region. On one hand, these findings imply that improvement in education significantly reduces environmental pollution in the short run while on the other hand the findings suggest that in both the short run and the long run more environmental damages are associated with increased improved education. This is an indication that the current educational system in the region does not encompass efforts to educate people on the need for a sustainable environment. The study signifies that the impact of education on emissions could differ based on economic methodology.

The study also found that energy consumption is positively related to environmental emissions. This suggest that more energy use harms our environment by raising the level of carbon emission. It also suggests that consuming non-clean energy is hazardous to our environment and it undermines efforts for achieving sustainable development. The region needs to make a reasonable shift to consuming clean energy to enable it to accomplish a targeted sustainable growth and environmental friendliness in line with sustainable development goals of 7 and 13 of United Nations (UN).

Despite the results from the study, the importance of education in mitigating $C0_2$ emissions cannot be ignored. However, it is emphasized that education in the region should be improved to include curriculum on environmental pollution and the role of individuals in curbing $C0_2$ emissions to safeguard the environment. Similarly, education can be taken out of the classroom to public places in the form of public sensitizations against carbon-emitting activities. Such form of education will cover those individuals who are unable to assess classroom education such as traders in marketplaces among other groups of people.

This study may not be suitable for policy use regarding individual countries in Sub-Saharan Africa given that its sample is a group of countries in the region. To this effect, it is suggested that future studies be carried out for individual countries to serve the policy needs of various countries. Also, future studies can consider using Ecological Footprints as a proxy for the environment as it relates to natural resources in the environment.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table A.1.

Table A.1
List of countries in sample.

West Africa	Southern Africa	Central Africa	East Africa
Benin	Botswana	Angola	Burundi
Burkina Faso	Lesotho	Cameroon	Democratic Republic of the Congo
Ghana	Madagascar	Central African Republic	Kenya
Guinea	Malawi	Chad	Rwanda
Guinea-Bissau	Mozambique	Ethiopia	Sudan
Ivory Coast	South Africa	Gabon	Tanzania
Mali			Uganda
Mauritania			Zambia
Niger			
Nigeria			
Senegal			
Togo			
t=19	t=19	t=19	t = 19
i=12	i=6	i=6	i = 12
N=228	N=114	N=114	N = 152

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