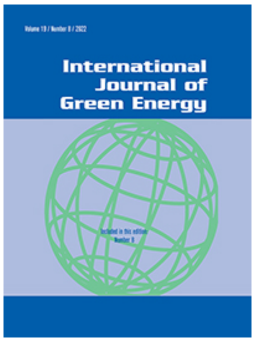

International Journal of Green Energy

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ljge20

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To cite this article: Yaw Sarpong Steve, A. Bein Murad, Bright Akwasi Gyamfi, Festus Victor Bekun & Gizem Uzuner (2022) Renewable energy consumption a panacea for Sustainable economic growth: panel causality analysis for African blocs, International Journal of Green Energy, 19:8, 847-856, DOI: 10.1080/15435075.2021.1966793

To link to this article: https://doi.org/10.1080/15435075.2021.1966793

Published online: 26 Aug 2021.

INTERNATIONAL JOURNAL OF GREEN ENERGY
2022, VOL. 19, NO. 8, 847–856
https://doi.org/10.1080/15435075.2021.1966793

Renewable energy consumption a panacea for Sustainable economic growth: panel causality analysis for African blocs

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ABSTRACT

The issue of increased renewable energy consumption has been widely debated, and this has become a central energy policy concern for developing and developed countries. The existing literature provides evidence that there is a positive relationship between energy consumption and economic growth in developed economies. However, findings in respect of developing/emerging economies remain inconclusive. Thus, this paper aims to investigate the impact on renewable energy consumption on economic growth by controlling other macroeconomic variables for regions of Sub-Saharan Africa (East, Central and West) covering the 1990–2018 sample period. For this purpose, common correlated effects mean group estimator (CCEMG) and Dumitrescu-Hurlin Granger causality test approach are used to consider both cross-sectional dependency and cross-country heterogeneity across countries. The CCEMG result indicates that an increase in renewable energy consumption led to reduction in economic growth even when the sample is analyzed based on geographical locations as East, West, and Central Africa. Granger causality results validate the feedback hypothesis for only Central Africa; the growth hypothesis is supported for East and West Africa. The empirical results suggest that energy planners, governments, and policy makers must act together to increase the renewable energy consumption share in her energy mix to promote economic growth for regions of Sub-Saharan Africa.

ARTICLE HISTORY
Received 18 November 2020
Accepted 7 August 2021

KEYWORDS
Renewable energy consumption; economic growth; carbon reduction; environmental sustainability; emerging economies; ccemg; panel econometrics

1. Introduction

According to the International Energy Agency (IEA) from 1990 to 2008, there been a rise regarding the consumption of energy from both renewable and non-renewable sources among regions around the world with the highest coming from the Middle East at 170%, followed by China 146%, then 66% for Latin America, India 91%, Africa 70%, United States increased by 20%, and the EU-27 part by 7% (Bilgili et al. 2017). In summary, globally the energy consumption rose significantly above 39% showing the greater need to develop sustainable strategies of energy sources (Mrabet et al. 2019). The Agency has also predicted that by the year 2050, the world will be able to grow the proportion of electricity generation from renewable sources by 39% which is a higher jump from 18.3% in 2002, and this would go a long way to reduce CO_2 emissions by 50% and also encourage economic growth above 50% (Mrabet et al. 2019). Energy consumption through renewable sources has received massive attention in recent times as environmental protection and wellbeing has taken center stage in most energy policies globally (Aydin 2019). Certain stringent steps have been taken to identify and implement different strategies, which are targeted at reducing the bad effects of energy consumption by resorting to renewable energy. However, taking into account the global pressures to economic growth, various stakeholders aim at most efficient solutions, minimizing the costs involved while at the same time ensuring the social benefits (Dogan and Inglesi-Lotz 2017). The agenda to ensure a sustainable energy world have been held high by the United Nations as they have declared that from the period 2014 up to 2024, this should be recognized a time for Sustainable Energy around the World (SE4All, 2014). Currently, renewable energy is a great source of employment for the poor as it has served as a platform for job creation, providing electricity access to the poor in rural settings and contributing to clean environment through reduced carbon emissions (Bhattacharya et al. 2016). Today, energy sources such as wind, solar, and hydro are essential ingredients contributing to cheap and reliable renewable energy sources thereby affecting growth. According to Bilgili and Ozturk (2015), biomass is a newly discovered source of energy which is gaining much prominence because of the contribution it brings on board the energy circles. Also, a plethora of studies have proven the contribution of renewable energy demand on economic growth and how economic growth will demand high levels of energy use (Apergis and Payne 2012; Sharma 2011). However, this current analysis is based on the income-emissions-induced environmental degradation hypothesis, which is based on the linear trade-off regarding carbon emissions and income level, also known as the Environmental Kuznets Curve in the energy literature. Energy use and trade have been described as significant sources of emissions. The EKC hypothesis (linear version) highlights the reverse connection between income level and environmental sustainability lends support to this current study (Gyamfi et al. 2021a; Stern 2004). The World's energy consumption leads to environmental degradation (fossil fuel-based energy) is the most available source of energy worldwide,

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resulting in environmental pollution. Therefore, this current analysis progresses the liner trade-off regarding renewable energy consumption as well as income level by incorporating trade openness, labor force and urbanization a trend into an enhanced renewable energy consumption-economic growth function.

The relationship between energy use and economic growth is not static for all countries as the dynamics change from one country to the other irrespective of the fact that they bear commonalities such as geographical location (Adewuyi & Awodumi, 2017). Several research studies have been carried out to investigate the relationship renewable energy consumption and economic growth in the energy literature. Comparisons have been made among countries, regions and groupings but in all, results have always led to conflicting conclusions irrespective of the methods, contexts, and analysis and moment conditions (Omri, Mabrouk, and Sassi-Tmar 2015; Ozturk and Bilgili 2015; Rafindadi 2016). Therefore, the linkage between renewable energy consumption and economic growth remains inconclusive, since the empirical findings show changes regarding to the country or region. Thus, this paper contributes to the nexus between renewable energy-economic growth literature in a number of ways. First, this study extends the previous literature by incorporating of labor force, trade openness, urbanization, and foreign direct investment into existing renewable energy consumption-economic growth model to avoid any misspecification problem. Second, to the best of the authors' knowledge this is the only study to evaluate the economic complexities building around renewable energy use leading to increased growth in each region of the sub-Saharan African. Generally, most of the studies including (Acheampong, 2018; Mrabet et al. 2019; Rafindadi 2015; Rafindadi and Mika'Ilu 2019; Rafindadi and Ozturk 2017; Sharif 2011) tried to analyze the influence of renewable energy consumption on economic growth for the Asian and developed economies. Given the large amount of renewable energy sources in Africa, it will be interesting for African countries to find out whether shifting to renewable energy consumption will be beneficial for economic growth. Third, this study takes into account cross-sectional dependency and cross-country heterogeneity across countries by using second generation panel estimation techniques with largest sample period.

The rest of the paper continues with literature review in section 2, section 3 presents the methodology, 4 presents the results and discussions and section 5 concludes with policy recommendations.

2. Literature review

Several studies have been carried out to explore the relationship between energy consumption and economic growth based on four well-known hypotheses. The first referred to as the growth hypothesis which indicates one-way causality from energy consumption to economic growth. It claims that energy is crucial input for production; thus, economic growth is dependent on the changes in energy policy or energy consumption (Gyamfi, Bein, and Bekun 2020b; Zafar et al. 2019). The second one is the conservation hypothesis which states that one-way causality from economic growth to energy consumption. It posits that changes in economic growth have impact on energy consumption (Destek and Aslan 2017). The third is feedback hypothesis, which means that two-way causal link between energy consumption and economic growth. This relation occurs when there is a dependency between both variables (Aydin 2019). The last, referred to as the neutrality hypothesis, states that there is no causality between energy consumption and economic growth (Ozcan and Ozturk 2019). The need of these hypotheses varieties can also be explained by the dynamics changes from one country to the other irrespective of the fact that they bear commonalities such as geographical location (Adeolu et al., 2017; Omri, Mabrouk, and Sassi-Tmar 2015).

Few existing ones such as (Mrabet et al. 2019; Zhao and Zhang, 2018; Al-Mulali, Fereidouni, and Lee 2014; Salim, Hassan, and Shafiei 2014; Gyamfi et al. 2021c) have found that the movement of people from the rural centers into the urban cities demand high levels of energy consumption but this has not been favorable for developing economies. As people move to urban areas the demand goes high for nonrenewable energy (Acheampong, 2018; Shahbaz et al. 2016; Sharif 2011). This study also concluded that prices of oil and income are also significant contributors for nonrenewable energy use from 1980 to 2014 in both developed and developing economies. Real income, renewable and nonrenewable energy demand have long run relationship (Apergis and Payne 2010, 2011; Ozturk 2010). In Latin America Al-Mulali, Fereidouni, and Lee (2014) established that in both long and short runs, electricity consumption from renewable sources promotes or contributes greatly to economic growth as compared to the nonrenewable electricity consumption sources. Also, investments, labor force as well as total exports and imports are drivers of growth.

According to Singh, Nyuur, and Richmond (2019), emerging economies have benefitted much from producing and utilizing renewable energy sources to impact positively on their economy in comparison with the developed nations. The study confirmed that comparatively the contribution of renewable energy production to economic growth for emerging and first-class economies is 0.07% and 0.05% respectively. While some studies found that, renewable energy consumption plays a very important role in promoting economic growth for both high income and emerging economies (Bhattacharya et al. 2016; Ito 2017; Ozturk and Bilgili 2015; Pao and Fu 2013; Rafindadi and Ozturk 2015; Shahbaz et al. 2020). There is a positive relationship between economic growth and renewable energy use in these economies. It is therefore evident that countries who rely on renewable energy consumption stand the chance of experiencing improved and sustained growth in all sectors of their economies. Further Gozgor, Lau, and Lu (2018) found a positive relationship between renewable and nonrenewable energy consumption and economic growth implying that these sources of energy are good to encourage the OECD countries to grow their economies. Other economic indicators such as institutional quality and human resources have high value also have positive influence if these countries are to experience growth that is able to sustain their existence. The most critical aspect that contribute much to the economic development agenda is the flow of foreign investments and the nature of the stock markets. The essential step for countries who are still in their developing stages as a matter of importance are encourage to have a greater proportion of their energy consumption from renewable sources such as biomass (Paramati, Ummalla, and Apergis 2016; Tamazian and Rao 2010; Gyamfi, Sarpong, and Bein 2021d; Gyamfi, Ozturk, Bein and Bekun, 2021e). Studies such as (Singh, Nyuur, and Richmond 2019) in the energy economics have argued that labor force is not a driver of economic growth as it does not impact positively on the renewable energy consumption of developing countries as a result of obsolete technology and equipment and lack of capacity.

On the other hand in the case of high developed countries labor force go a long way to improve economic growth through renewable energy use due to high technological know-how and proper institutional arrangements. Apergis and Payne (2011). Nevertheless, the impact of renewable and nonrenewable energy consumption on economic growth is not constant for all economies. Balcilar et al. (2018) argue that the G7 countries experience levels of impact in different times across the countries. Most especially in the aftermath of the 1990, these Canada, France, Japan, and the UK have really resorted to renewable energy consumption which is having great impact on its economy and increasing growth. Maji, Sulaiman, and Abdul-Rahim (2019) reports that renewable energy does not encourage economic growth in the SSA region due to its heavy dependency on biomass use which is not environmentally friendly and harmful to peoples' health. Biomass consumption is not favorable for economic growth in West Africa. Several scholars (Ohlan 2016; Rafindadi and Ilhan 2017; Rauf et al. 2018; Sebri and Ben-Salha 2014; Shahbaz et al. 2015; Sharif et al. 2019) argue that opening up an economy for increased trading activities and a vibrant financial sector is an essential ingredient for economic growth. For example, Ohlan (2016) found that India's economy could take advantage of nonrenewable energy sources and its financial sector and develop these areas in such a way that it will engender growth and development. The implication is that if India becomes reliant on energy sources such as fossils and do not invest in renewable sources such as biomass, it could in the long run delay growth as it will be expensive to sustain the nonrenewable sources. Improvement in different sources of electricity energy for example is encouraging to trigger growth (Aydin 2019). Several studies (Bhattacharya et al. 2016; Kahia, Ben Aïssa, and Charfeddine 2016) argue that renewable and nonrenewable energy consumption will have a strong impact positive impact on economic growth in the short run but renewable energy consumption will not have any significant impact during those periods. On the other hand economic growth encourages countries to consume renewable energy as compared to nonrenewable energy sources. Doğan (2017) concluded that tourism is a good source of encouraging energy demand to engender growth through increased demand for goods and services. When opportunities are created for the labor force to get jobs through renewable energy consumption it becomes a catalyst for improved incomes and well-being (Bilgili, Koçak, and Bulut 2016; Chiu and Chang 2009; Dogan and Seker 2016; Jebli, Youssef, and Ozturk 2016; Shafiei and Salim 2014). Ntanos et al. (2018) where other things pertaining to economic growth do not change, an increase in the renewable energy use in an average country will lead to a jump in real growth in income. Thus, some scholars conclude that different renewable energy sources such as those from biomass, geothermal, wind and solar and hydroelectricity some countries benefit immensely from them and encourage growth (Apergis and Payne 2012; Salim, Hassan, and Shafiei 2014). However, Bhattacharya et al. (2016) find a rather an unfavorable relationship between renewable energy consumption and economic growth and concludes that there is a negative relationship between the two variables. Charfeddine and Kahia (2019) analyzed the impact of renewable energy consumption and financial on CO_2 emissions and economic growth in the Middle East and North African context from 1980 to 2015. The study found that the countries are in their developing stages to be able to take full advantage of renewable energy sources to greatly impact on growth. In this regard, this source of energy is having a negative impact on economic growth in developing economies as growth leads to renewable energy use (Bekun, Emir, and Sarkodie 2019; Ocal and Aslan 2013). Furthermore, on the basis of autoregressive distributed lag (ARDL) model estimation technique, Dogan and Ozturk (2017) obtained the increases in renewable energy consumption reduce environmental degradation for the US. Financial development, trade openness, and increased use of renewable energy and nonrenewable energy will cause economic growth(Yazdi and Beygi, 2018; Paramati et al. 2018). Furthermore, Nguyen and Kakinaka (2019) argue that low-income countries are not able use renewable energy sources to boost the economy to engender growth neither is it able to help reduce pollution that come from CO_2 because of high level of investment in renewable energy production.

3. Materials and methodology

3.1. Materials

This study utilized yearly data on renewable energy consumption (REC), real per capita gross domestic product (EG), labor force (LF), urbanization (URB), trade openness (TO) and foreign direct investment (FDI). REC is measured as the percentage of final energy consumption in the equivalence of kg of oil; real GDP per capita stands for economic growth and is calculated in constant 2010 USD dollars; TO is the total import and export of goods and services as a percentage of GPD; FDI is measured as the net inflows of investments calculated in constant 2010 US dollars and LF stands for the total population of people from age 15 and above who are either working, seeking job or are unemployed. All the data were sourced from the World Bank World Development Indicators (2018). Our sample were made up of 33 countries, and they were chosen to be part purely based on current data availability for the period 1990 to 2018. The variables for the study were converted into natural logs to enable interpretation in elasticities and to address issues of heteroscedasticity. The study was mainly concentrated on examining the dynamics of the variables in three different blocks in the sub-Saharan Africa according to geographical locations namely West, East, and Central Africa. Tables 1 and 2, in the Appendix to this paper offer definitions of the variables, their measurement as well as list of countries per geographical locations, respectively.

3.2. Methodology

To investigate the dynamic relationship between EG, REC, TO, FDI, LF, and URB, firstly, it is necessary to test the existence of cross-sectional dependency (CD) and heterogeneity. The validation of CD and heterogeneity, is a condition to use second-generation panel estimation techniques. With this aim, Pesaran and Yamagata (2008) bias-adjusted LM test, Pesaran (2004) CD test, Pesaran (2004) Scaled LM test, and the Breusch and Pagan (1980) LM test are used to check the existence of CD for the selected variables. Then, slope homogeneity test of Pesaran and Yamagata (2008) is employed. Per the results as presented in Table 3, there is heterogeneity among variables and interdependency across each region of the Sub-Saharan countries. Therefore, this study employs second-generation estimation methods.

Next, we employed the CIPS panel unit root test, which is proposed by (Pesaran, 2007). It helps us to determine the order of integration of the selected variables. As shown in Table 4, the integrated order of the variables under consideration is 1, i.e I (1), then our next step is to check the existence of long-run relationship between the variables by using Westerlund cointegration test. After establishing cointegration, we then utilized the common correlated effects mean group estimator (CCEMG) of Pesaran (2006) to establish long-run relationships. This technique is more powerful than the ordinary least squares (OLS) as it provides robust standard errors and accurate coefficients. Lastly, we performed the Dumitrescu and Hurlin (2012) Granger causality test to establish the direction of causalities between the variables. This test is powerful to take care of problems that are associated with cross-dependence panel data sets by utilizing Monte– Carlo simulations.

3.3. Model specification

There has been a traditional way of modeling the energy–growth relationship in past. This is referred to as the K-L model (Apergis and Payne 2010, 2011). This model takes real GDP per capital to stand for Y, which is a function of capital (C) and labor (L). The following is the mathematical representation of the model;

$$Y = f(K, L) \tag{1}$$

The following results will be obtained when the equation is divided by L:

$$Y/L = f(K/L) \tag{2}$$

when REC is introduced in the model in Eq. (2), the results below are obtained;

$$Y/L = f(K/L, REC) \tag{3}$$

It is worth replacing the term K/L with TO, FDI and LF because they are also important in determining productivity within the structure of the economy, thus (K/L). So the growth model will show as follows;

$$Y/L = f(REC, TO, FDI, LF, URB) \tag{4}$$

Since empirically eq. (4) takes into account TO, FDI, LF and also REC it becomes the basis for proving the contribution of these variables in the energy-growth relationship for the sampled countries.

From eq. (4), the model is grounded on the basis of the following background and generally given as follows;

$$(Y/L)_{it} = f\left(REC_{it}^{\propto 1}, TO_{it}^{\propto 2}, FDI_{it}^{\propto 3}, LF_{it}^{\propto 4}, LURB_{it}^{\propto 5}\right) \tag{5}$$

For empirical analysis, then the model is given its definition in natural logarithm in the following specification;

$$\frac{\log Y}{L} = \propto_0 + \propto_1 logREC_{it} + \propto_2 logTO_{it} + \propto_3 logFDI_{it} + \propto_4 logLF_{it} + \propto_5 logLURB_{it} + \in_{it} \tag{6}$$

where, $\propto_1$, $\propto_2$, $\propto_3$, $\propto_4$,$\propto_5$ stand for elasticities of output regarding renewable energy consumption of a country (REC_{it}), trade openness (TO_{it}), foreign direct investment (FDI_{it}), labor force (LF_{it}) and urbanization (URB_{it}), respectively. i is country and t is time. The error term is denoted by $\in_{it.}$

4. Empirical Results

This section of this study focuses on the preliminary analysis of the variables under consideration

The correlation matrix is shown in Table 1. The results proved that economic growth is highly negatively associated with renewable energy consumption. Also, economic growth was negatively and highly correlated with labor force and urbanization. There is also a higher association with trade openness and economic growth, and this association is positive. Again, economic growth has a positive significant association with foreign direct investment. Renewable energy consumption and trade prove to have significant correlation

Table 1. Correlation Matrix.

	TO	LF	FDI	EG	REC	URB
TO	1.000000					
LF	−0.193248*	1.000000				
FDI	0.229791*	0.328860*	1.000000			
EG	0.272208*	−0.440936*	0.325228*	1.000000		
REC	−0.269527*	0.326287*	−0.119794*	−0.637009*	1.000000	
URB	−0.117206*	0.169748*	0.069878*	−0.238109*	0.281499*	1.000000

Note: * denote significance at 1% level.

but this is negative. The results suggest that renewable energy consumption does not drive growth in the countries under study.

Descriptive statistics for each of the variables for each geographical area and aggregate are presented in Table 2. The average economic growth rate for the countries in group stood at 6.75%. Central Africa experience annual growth above the group average of 6.75% growing at 7.34%. The lowest growth was recorded by East Africa growing at 6.57% annually below the average real GDP per capita growth rate. In terms of annual consumption of renewable energy, the average consumption for the aggregate countries was 4.24%. East Africa had the highest consumption rate at 4.26%, followed by West Africa consuming 4.23% all above the average and the lowest is Central Africa at 4.20% reaching the average consumption rate.

Prior to testing unit root properties of the selected variables, cross-sectional dependence test (CD) is applied to investigate the presence of common shock across the countries. The CD test results in Table 3 indicate the rejection of the null hypothesis of cross-sectional independence in all variables for each geographical area. It implies that the first-generation test techniques are not suitable for this study (Pedroni 1999). Furthermore, Table 3 presents the results of the slope homogeneity test which is developed by Pesaran and Yamagata (2008). According to Table 3, the probability of the delta test is less than 1% significance level. Thus, there is a heterogeneity across each region of Sub-Saharan Africa countries for the selected variables. Therefore, the second-generation estimation techniques are used in this study. With this aim, the analysis proceeds to test integration order of the variables, using CIPS test, which is robust to cross-sectional dependence. Table 4 presents the result for CIPS unit root test. According to Table 4, all variables for each geographical area are non-

Table 4. Unit root test Result.

	CIPS	
Variable	Level	First Difference
Central Africa		
REC	−1.557	−3.578*
TO	−0.446	−3.198*
FDI	−2.11	−4.356*
LF	−2.089	−3.552*
URB	−1.294	−2.661**
West Africa		
REC	−1.262	−4.022*
TO	−1.348	−3.875*
FDI	−1.032	−4.459*
LF	−2.044	−2.459**
URB	−1.484	−2.709*
East Africa		
REC	−1.98	−2.394**
TO	−1.37	−4.030*
FDI	−1.834	−2.810*
LF	−1.725	−2.340**
URB	−1.98	−2.394**

Note: * and ** stand for 1% and 5% significance levels, respectively.

Table 3. The results from the Cross-Sectional Dependence and the heterogeneity.

Variable	LM	CD-LM	CD	LMADJ Δ
Central Africa				
REC	118.453*	15.037*	−2.572*	12.215* 33.07*
TO	143.004*	18.826*	−3.107*	12.61* 24.65*
FDI	68.510*	7.331*	−3.578*	2.542** 23.32*
LF	181.969*	24.838*	−2.558**	35.717* 17.81*
URB	158.776*	21.259*	−3.139*	22.068* 35.00*
West Africa				
REC	97.625*	29.594*	5.371*	22.617* 34.37*
TO	70.562*	31.430*	−3.155*	18.786* 42.81*
FDI	86.027*	11.852*	−2.386*	6.687* 30.72*
LF	46.500*	53.523*	−3.374*	52.917* 24.19
URB	61.216*	43.332*	−2.912*	10.239* 37.52*
East Africa				
REC	93.746*	28.527*	−2.978*	16.546* 16.98*
TO	82.533*	27.551*	−2.833*	17.223* 31.05*
FDI	211.608*	12.674*	−3.506*	5.113* 25.83*
LF	68.530*	35.036*	−3.391*	36.757* 19.26*
TO	71.467*	26.588*	−3.129*	27.169* 27.03*
URB	81.242*	33.411*	−2.021*	37.243* 17.91*

Note: * denote significance at 1% level. Δ indicates the heterogeneity test.

Table 2. Descriptive statistics and the results of the heterogeneity test.

Central Africa						
	EG	**FDI**	**LF**	**REC**	**TO**	**URB**
Mean	7.347424	18.84946	13.97798	4.208889	4.195436	1.330399
Median	7.059914	19.36108	14.39160	4.426364	4.209931	1.362008
Maximum	9.928811	22.91567	17.12377	4.588457	5.055365	2.064465
Minimum	5.620604	13.45576	9.053212	1.677489	1.621663	−1.680781
Std. Dev.	1.315631	2.135002	2.342889	0.661481	0.485188	0.444560
West Africa						
Mean	6.614508	18.36497	14.82797	4.239340	4.163928	1.341590
Median	6.578832	18.46947	14.88834	4.346715	4.117358	1.374605
Maximum	7.934000	22.95500	17.87060	4.553759	5.740931	2.162038
Minimum	5.609439	10.59663	12.64000	3.380980	3.138066	−1.380432
Std. Dev.	0.489466	2.217993	1.180913	0.280501	0.372702	0.347454
East Africa						
Mean	6.570667	17.82813	15.15755	4.262639	3.841811	1.316634
Median	6.434115	18.40595	15.62070	4.404474	3.863519	1.467467
Maximum	9.251734	22.80715	17.02935	4.577711	4.920799	2.862148
Minimum	5.299806	4.605170	11.43545	2.004045	−0.228342	−4.999263
Std. Dev.	0.847595	2.987575	1.400326	0.467826	0.576696	0.706856
Group						
Mean	6.753887	18.25198	14.76758	4.241355	4.053815	1.330236
Median	6.584572	18.60274	15.04270	4.388381	4.033941	1.380133
Maximum	9.928811	22.95500	17.87060	4.588457	5.740931	2.862148
Minimum	5.299806	4.605170	9.053212	1.677489	−0.228342	−4.999263
Std. Dev.	0.907015	2.547993	1.627995	0.453597	0.504813	0.522226

Table 5. Westerlund Cointegration test Results.

	Central Africa		West Africa		East Africa		Group	
Mod specification: Constant								
	Stat	p-value	Stat	p-value	Stat	p-value	Stat	p-value
DHp	−1.967**	0.025	0.712	0.786	1.493	0.932	−1.131	0.129
DHg	−1.612***	0.053	−1.989**	0.023	−2.103**	0.018	−1.950**	0.026
Mod specification: Constant and trend								
	Stat	p-value	Stat	p-value	Stat	p-value		
DHp	−1.639***	0.051	−1.531***	0.063	0.068	0.527	−0.914	0.180
DHg	−2.004**	0.023	−2.103**	0.018	−2.030**	0.021	−1.974**	0.024

Note: ** and *** show significance at the 5% and 10% significance levels, respectively.

stationary at their level form, but they all turn to stationary after taking their first difference. Overall, we can conclude that the selected variables for each geographical area are integrated of order one, i.e. I (1). The unit root test then tells that it is likely that there is a long-run elasticities in relationship among the variables as they are all integrated with same order and that even though they fluctuate, but they came back to their deterministic trending average.

After ensuring the stationarity of our panel variables, the Westerlund (2008) cointegration test is employed to investigate the cointegration relationship between the selected variables. The test results are presented in Table 5. The empirical evidence shows that the null hypothesis of no cointegration can be rejected in most cases for all regions. In another way, there is a long-run relationship between renewable energy consumption, economic growth, labor force, trade openness, foreign direct investment and urbanization in each region and group of regions for the period of 1990–2018.

4.1. Long run-elasticities

CCEMG *for economic growth*

In light of the empirical evidence of cross-sectional dependence and long-run relationship between the variables, the study employed the CCEMG estimation technique (Pesaran 2006) to establish the magnitude of long term elasticities of the variables for each geographical location and group. Table 6 presents the results from the CCEMG estimations for the individual locations and as a group (Smyth and Narayan 2015). The overall results support the conservative hypothesis for the countries under study. According to Table 6, the results show that 1% rise in renewable energy consumption will reduce economic growth by a magnitude of 1.02%, 0.56%, and 0.18% for Central, West, and East Africa, respectively. Findings in respect of the group show similar results that a 1% rise in renewable energy consumption will significantly decrease economic growth by 0.18%. This result is consistent with (Kahia, Ben Aïssa, and Charfeddine 2016; Nguyen and Kakinaka 2019; Ohlan 2016; Sarpong et al. 2020) and contrary to (Khoshnevis and Beygi 2018). The findings may be due to the fact that the countries are still in their developing stages and do not have the needed capacity to turn the abundant renewable energy sources into good use. Again, lack of improved infrastructure to support renewable energy production, low technological know-how and absence of access to finance in the renewable energy production all come together to militate against its impact on growth. As a group, an increase in trade, urbanization and labor force will increase economic growth for the various regions which is consistent with (Ohlan 2016; Dogan, 2015) but in contradiction to (Singh, Nyuur, and Richmond 2019). In West and East Africa, a 1% rise in labor force is favorable for economic growth as it will result into a significant increase of 0.60% and 0.53%, respectively. The result implies that labor force is a good economic indicator to engender growth in sub-Saharan Africa countries probably because the conditions for meeting the labor requirements in the area of renewable energy production has been met. The right level of human capacity has been built for example in the area of capturing the actual sales levels accrued from renewable energy consumption. A 1% increase in trade openness and foreign direct investment will result into increase in economic growth in all the geographical locations consistent with (Sebri and Ben-Salha 2014; Shahbaz et al. 2016) but contrary to (Paramati et al. 2018). The results imply that 1% increase in the trading arrangements for market flexibility and higher inflows of direct foreign investment into the countries will trigger increased income per capita. In sum, it could be seen that heavily depending on renewable energy sources for consumption is not favorable for economic well-being of emerging economies such as those that have been studied. It is therefore appropriate for these countries to find more reliable sources of energy consumption such as the nonrenewable energy as has been found Mrabet et al. (2019) that nonrenewable energy consumption increases economic growth in emerging and underdeveloped countries. The results also show that the threshold consumption approach of Chen, Pinar, and Stengos

Table 6. CCEMG **test Results.**

	Central Africa		West Africa		East Africa		Group	
	Beta	t-stat	Beta	t-stat	Beta	t-stat	Beta	t-stat
REC	−1.017*	−33.457	−0.564*	−13.750	−0.177**	−2.140	−0.181*	−6.235
URB	0.002*	4.346	0.001*	21.740	0.001*	7.467	0.061*	5.311
FDI	−0.001*	−10.240	0.006*	10.800	−0.001*	−6.419	−0.000	−0.962
TO	−0.116**	−2.524	0.035*	11.890	0.002	0.7252	0.002*	5.189
LF	0.547*	9.661	−0.596*	−15.700	−0.599*	−2.565	0.462*	17.130

Note: *, **, *** denote significance at 1%, 5% and 10% level.

Table 7. Dumitrescu-Hurlin Granger Causality test Results.

Null Hypothesis	Z-bar	Probability
Central Africa		
REC ≠> EG	17.120*	0.000
EG ≠> REC	8.107*	0.000
LF ≠> EG	9.805*	0.000
EG ≠> LF	3.444**	0.010
TO ≠> EG	3.156*	0.002
EG ≠> TO	0.386	0.697
URB ≠> EG	22.454*	0.000
EG ≠> URB	3.947*	0.001
FDI ≠> EG	3.295*	0.000
EG ≠> FDI	2.189**	0.029
West Africa		
REC ≠> EG	3.936*	0.000
EG ≠> REC	0.946	0.852
LF ≠> EG	9.175*	0.000
EG ≠> LF	0.9474	0.343
TO ≠> EG	2.285**	0.022
EG ≠> TO	8.900*	0.000
URB ≠> EG	14.809*	0.000
EG ≠> URB	2.680*	0.001
FDI ≠> EG	8.991*	0.000
EG ≠> FDI	9.514*	0.000
East Africa		
REC ≠> EG	3.852*	0.000
EG ≠> REC	4.922	0.405
LF ≠> EG	10.415*	0.000
EG ≠> LF	8.465*	0.000
TO ≠> EG	2.251**	0.024
EG ≠> TO	6.988*	0.000
URB ≠> EG	1.553	0.120
EG ≠> URB	6.794*	0.000
FDI ≠> EG	3.100**	0.020
EG ≠> FDI	3.181*	0.000
Group		
REC ≠> EG	2.141**	0.032
EG ≠> REC	2.941**	0.012
LF ≠> EG	6.915*	0.000
EG ≠> LF	1.620	0.205
TO ≠> EG	3.216*	0.001
EG ≠>TO	3.143*	0.002
URB ≠> EG	6.431*	0.000
EG ≠> URB	7.310*	0.000
FDI ≠> EG	6.520*	0.000
EG ≠> FDI	1.232	0.218 W

Note: The symbol "≠>" denotes the non-Granger causality and the subscripts *, ** indicate significance level at 0.01% and 0.05%.

(2020) would hold in the sense that may be the countries are still developing and have not consumed renewable energy to the threshold that could impact strongly in increasing growth.

4.2. *Dumitrescu and Hurlin (2012)* Granger Causality Test Results

Even though results from the CCEMG provide substantial amount of credible and reliable results for inferences, there is a need to investigate the causal link between variables as the empirical results ideally offer policy-oriented insights from the estimation procedure (Dogan and Seker 2016). Therefore, this study proceeds with the Dumitrescu-Hurlin Granger causality test to find out the Granger causality relationship between the variables. This test was adopted because it provides flexibility for use with cross-sectional dependence and heterogeneous panel data. Table 6 and 7 reports the results of the Dumitrescu-Hurlin causality test. These results reveal that there is unidirectional causality running from renewable energy consumption to economic growth for East and West Africa. These findings are similar with the study of Dogan and Seker (2016), Ocal and Aslan (2013), Bekun and Gyamfi (2020) and Adedoyin et al. (2021). Also, it supports the notion that the adoption of clean energy sources such as renewable energy may actually trigger the economic growth. However, there is a significant bidirectional Granger causal link between renewable energy consumption and economic growth for Central Africa and group of regions. This is consistent with the previous study of Kahia, Ben Aïssa, and Charfeddine (2016). There are also notable evidences of bidirectional Granger causal link between labor force and economic growth for East and West Africa. The implication of this result is that labor force stands to be a critical aspect of economic growth and has an impact for improving economies. In addition, there is unidirectional causality flow from trade openness to economic growth for Central Africa which is consistent with the study of Paramati et al. (2018). Moreover, there are bidirectional Granger causalities between foreign direct investment and economic growth. This result indicates that foreign direct investment is an engine for growth and therefore policy makers should make it a point to put in place encouraging monetary policy tools that will for example improve domestic currencies and encourage foreign direct investment. Tax holidays could be extended to investors as incentives to boost the local economies. A more flexible export and import trade agreements is essential to boost the economies since technology and knowledge spillovers could help improve these economies. In general, these findings show that the past values of renewable energy consumption, labor force, trade openness, and urbanization have additional information, which help to predict the future values of economic growth for each region of Africa.

Emerging economies like that of the sub-Saharan Africa faces enormous challenges regarding energy consumption. The IEA has made it clear that by the year 2030 there is likely to be energy deficit, and this will become a bigger concern for the region given the pace of its growing population and activities (Bilgili et al. 2017). In order to contribute to the debate, this paper is the first of its kind to analyze the dynamics of the influence of renewable energy consumption and urbanization on economic growth in 33 sub-Saharan African countries. The countries were divided into geographical locations as East Africa, West Africa, and Central Africa. We utilized renewable energy consumption, urban population growth, trade openness, labor force, and foreign direct investment as drivers of economic growth. The heterogeneity and cross-sectional dependency properties were taken into account across the panel. We also ensured that interdependencies and geographical differences were established across our sample.

The empirical results from the CCEMG technique prove that renewable energy consumption has a negative impact on economic growth and that it is not an ideal energy source for emerging economies. In the context of the sub-Saharan Africa, according to the empirical findings of this study the conservation hypothesis exists for the relationship between renewable energy and economic growth. This is because renewable energy involves high cost and require immense resource investment. For this reason, looking at the financial and human resource base of the region, it will be important to consume energy sources that are less expensive and less harmful as compared to renewable energy sources. This means that the contribution of renewable energy consumption is not significant enough to greatly impact on growth and development as compared to other sources of energy. In summary, our findings could not establish a robust relationship between economic growth and renewable energy consumption and the strong relationship running from renewable energy consumption to economic growth either in terms of geographical locations or as a group. We could therefore not identify that in the long-run renewable energy consumption will encourage economic growth in any of the geographical locations that were considered for this study.

Furthermore, the argument that a change in economic growth will cause changes in renewable energy consumption was also not confirmed. Rather labor force was realized as a greater factor to induce growth in the economies of sub-Saharan African countries. This is a wake-up call for governments of these countries to ensure that population who are within the working class are given the necessary support and resources to be able to participate fully in the development agenda. Issues such as labor entitlements in the area of for example study leave or sick leave must be enforced in all labor agreements within in the energy sectors. Rural development could take a chunk of the economic activities so that resources could be evenly distributed to reduce the renewable energy need in the urban centers.

The policy implications for this study are that governments of these countries should take advantage of the abundance of renewable energy sources in their countries in order to expand renewable energy consumption. The unidirectional relationship that was found between economic growth and renewable energy consumption is a concern for policy makers to have a greater attention for a more sustainable energy consumption source to meet the IEA agenda. This will help to reduce the dependency burden on external energy sources, avoid the instability in world oil and natural gas prices and the consequential effects of CO_2 emissions. Also bottlenecks within the energy sector that are capable of militating against growth should be curtailed. In addition, energy authorities should take steps to increase the share of renewable energy sources so that it can have a significant impact on growth. Lastly, there should be quality institutions to avoid and prevent corrupt practices within the energy sector.

Acknowledgments

Author gratitude is extended to the prospective editor(s) and reviewers that will/have spared time to guide toward a successful publication.

Funding

I hereby declare that there is no form of funding received for this study.

Compliance with Ethical Standards

I wish to disclose here that there are no potential conflicts of interest at any level of this study.

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Table A1. Description of variables.

VARIABLES	MEASURMENT	SOURCES	SYMBOLS
Renewable energy	Renewable energy consumption (% of total final energy consumption)	WDI (2020)	REC
GDP per Capita	In constant 2010 USD	WDI (2020)	EG
Urbanization	Urban population (% of total population)	WDI (2020)	URB
Trade Openness	Trade (% of GDP)	WDI (2020)	TO
Foreign Direct Investment	net inflows (% of GDP)	WDI (2020)	FDI
labor force	(% of total population)	WDI (2020)	LF

Sources: author's compilation, 2021.

Table A2: Sub-Saharan African countries.

#	Central Africa	East Africa	West Africa
1	Cameroon	Burundi	Benin
2	Central African Republic	Comoros	Cote d'Ivoire
3	Chad	Eritrea	Gambia
4	Democratic Republic of the Congo	Kenya	Ghana
5	Republic of the Congo	Madagascar	Guinea
6	Equatorial Guinea	Malawi	Guinea Bissau
7	Gabon	Mauritius	Liberia
8		Mozambique	Mali
9		Rwanda	Mauritania
10		Sudan	Niger
11		Tanzania	Nigeria
12		Uganda	Senegal
13			Sierra Leone
14			Togo