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Rapid Urbanization and Carbon Dioxide Emissions in Africa

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Abstract

Africa continues to experience rapid growth in population and density which increased the amount of fossils fuels use. Fossil fuels produce large quantity of carbon dioxide and lead to climate change. This study examines the effects of urbanization, energy consumption on carbon dioxide emissions (CO_2) in Sub-Saharan African countries (SSA). The study used panel cointegration, vector error correction model (VECM), fully modified ordinary least square (FMOLS) and dynamic ordinary least square (DOLS). The empirical finding from cointegration test reveals that there exists a long run cointegrating relationship between energy consumption, urbanization and carbon dioxide emissions. The results based on Granger causality test indicate that energy consumptions and urbanization granger cause carbon dioxide emissions. The results from FMOLS and DOLS confirmed that energy consumptions and urbanization increase carbon dioxide emissions in the sample countries. This indicates that energy consumption (fossil fuel energy) and urbanization are among the major determinant of CO_2 emissions. Therefore, there is a need to have a policy that would help enhance the use of green energy to reduce the environmental damage.

Key words; Carbon dioxide emissions, Sub-Saharan Africa, Energy Consumption, Urbanization

JEL Classification: C23, O1, Q56

1. Introduction

The adverse effects of climate change on the environment are of immense concern to international organization and governments around the globe. The increasing level of CO_2 emissions due to rapid growth in population and urban density in the developing countries are believed to be responsible for the global warming. The Carbon dioxide (CO_2) emission as one of the greenhouse gases (GHG) is considered the most concentrated greenhouse gas in the atmosphere and has over a century atmospheric lifetime. Brundtland Commission Report (1987) declared that the accumulation of CO_2 is one of the serious environmental threats. The amount of CO_2 emissions in developing countries have increased significantly over the years, due to a rise in energy consumption

(Hossain, 2011; Al-mulali and Binti Che Sab, 2012).

The contribution of Africa as a continent to the global CO_2 emissions in small amounted 2% in 2018 but the trend indicates rising pace (EIA, 2019).As a result,the United States Energy Information Administration, projected that by 2040 energy-related carbon dioxide emissions in developing countries could be about 127% higher than emissions in advanced economies (EIA, 2016). Africa is one of the regions with rapid population growth in the world and the continent is expected to be 64% urban by 2050 (United Nations Population Division, 2014). The studies on urbanization and CO_2 emissions have been well documented in the literature. And most of those studies used data from economiesof Asia and Europe (Omri, 2013; Wang et al.; 2014; Acaravci& Ozturk, 2010) with some limited empirical results on carbon emissions and economic growth in African countries(Olubusoye& Musa, 2020; Dan'Asabe et al. 2021; Kwakwa, 2015). In the light of this reason, our study can render empirical evidences and important policy implications related to Sub-Saharan economies.

2. Literature review

Various empirical studies have documented the links between Urbanization, Energy Consumption and CO_2 Emissions. Apergis and James (2010) explore the relationship between carbon dioxide emissions, energy consumption and real output for 11 countries of the Commonwealth of independent states over the period 1992-2004. They found that in the long-run, energy consumption has a positive and statistically significant impact on carbon dioxide emissions while real output follows an inverted U-shape pattern associated with the Environmental Kuznets Curve (EKC) hypothesis. They found bi-directional causality between energy consumption and CO_2emissions in the long run. But the short run dynamics reveal a uni-directional causality running from energy consumption and real output, respectively, to carbon dioxide emissions and bi-directional causality between energy consumption and real output.

Kwakwa and Adu (2015) uses panel unit root analysis, panel cointegration analysis and the method of FMOLS (Fully Modified OLS) and DOLS (Dynamic OLS) through the period 1977-2012 in the case of countries in SSA region. Their results show the presence of long run relationship between income and carbon emissions. They concluded that both income and non-income variables explain carbon emissions in SSA, albeit income and energy consumption have a greater effect.

Zhang and Lin (2012) developed a study to investigate the impact of economic indicators on pollution (CO_2 emissions) in China during the period 1995–2010 by using the fixed effects model and the method of least square generalized linear regression. They utilize the demographic intensities, urbanization, GDP, industrial production, production of services, and energy consumption as economic indicators. The main results of their study show that the industrial production and GDP have an impact on CO_2 emissions.

Wang et al. (2011) confirm the existence of a relationship between energy consumption, economic growth and CO_2 emissions using panel cointegration and panel vector error correction modeling techniques based on the panel data for 28 provinces in China during 1995-2007. They found bi-directional causality between CO_2 emissions and energy consumption as well as between energy consumption and economic growth. The authors concluded that economic growth is the long-run cause for CO_2 emissions and CO_2 emissions and economic growth are the long-run causes for energy consumption.

Al-Mulali (2011) uses a panel model for the Middle East and North Africa (MENA) countries during the period 1980-2009. Based on cointegration test results, he found that CO_2 emission, and oil consumption has a long- run relationship with economic growth. The empirical results reveal also a bi-directional Granger causality between oil consumption and economic growth in the short and long run. The author concludes that oil consumption plays a crucial role in the economic growth of the MENA countries. Parshall et al. (2010) used spatial analysis in modelling the link between energy consumption and CO_2emissions at the urban scale. Their study found that urbanisation is among the most important determinants affecting energy consumption in United States. Apergis and Payne (2009) studied the causal relationship between carbon emissions, energy consumption, and GDP within a panel VECM for six Central American countries over the period of 1971–2004. The long-run results confirmed a positive effect of energy consumption on emissions. Granger causality test results from the authors showed short-run uni-directional causality from energy consumption, and real output to emissions, but long-run bi-directional causality was found between energy consumption and emissions.

Farhani and Rejeb (2012) applied the panel unit root tests, panel cointegration methods and panel causality test to investigate the relationship between energy consumption, GDP and CO_2 emissions for 15 MENA countries covering the annual period 1973-2008. To deal with the heterogeneity in countries and the endogeneity bias in regressors, the authors applied respectively the Fully Modified Ordinary Least Square (FMOLS) and the Dynamic Ordinary Least Square (DOLS) approach to estimate the long-run relationship between these three factors. Their finding revealed that there is no causal link between GDP and energy consumption; and between CO_2 emissions and energy consumption in the short run. However, in the long run, there is a uni-directional causality running from GDP and CO_2 emissions to energy consumption.

Acaravci and Ozturk (2010) investigate the dynamic relationship between income, energy consumption, trade openness and carbon emissions for 19 European countries by using Autoregressive Distributed Lag (ARDL) bounds cointegration analysis developed by Pesaranand Shin (1999) and Pesaran et al. (2001), and Error Correction Based Granger Causality models. The bounds F-test for cointegration test yields evidence of a long-run relationship between carbon emissions per capita, real gross domestic product (GDP) per capita and the square of per capita real GDP only for Denmark, Germany, Greece, Iceland, Italy, Portugal and Switzerland. Also, the cumulative sum and cumulative sum of squares tests reveal that the estimated parameters are stable for the sample period. To examine the impact of economic growth and energy consumption on environmental degradation in eight Asian economies during the period 1991- 2013, by using the cointegration test, the Fully Modified OLS, and the panel causality. They utilized the trade openness, economic growth, population, energy consumption and financial development as economic indicators. The main findings of Jamel and Derbali (2016) of their study revealed that economic growth have a positive impact on environmental degradation. According to them, Fisher (1932), Pedroni (1997) and Kao (1999) confirmed the presence of long run relationship between environmental degradation and economic growth. They concluded that the existence of bi-directional linkage between environmental degradation and economic growth in case of eight Asian economies. This finding was in agreement with Omri (2013); Omri (2013) uses the method of least squares generalized through the period 1990-2011 in the case of MENA region. He examined the impact of economic activity indicators on environmental degradation. He utilizes CO_2emission as proxy for pollution and, capital, financial development, population labour and GDP as indicators for economic activities. The results show the presence of a positive and significant impact of GDP and negative impact of financial development and capital on CO_2emission.

3. Methodology and Sources of Data

3.1 Sources of Data

Recall, the main objective of this study is to examine empirically the causal linkage between urban population, fossil fuel energy and carbon dioxide emissions in Sub-Saharan African countries covering the period 2001-2020. We employed annual panel data drawn from World Bank, World Bank Development Indicators (WDI 2022) online database. We sampled twenty-three Sub-Saharan African countries (Angola, Benin, Botswana, Cameroon, Congo Democratic Republic, Congo Republic, Cote d'Ivoire, Ethiopia, Gabon, Ghana, Kenya, Mauritius, Mozambique, Namibia, Niger, Nigeria, Senegal, Sudan, South Africa,Tanzania, Togo, Zambia and Zimbabwe).

3.2 Model Specification

To examine the effects and the causality between the energy consumption, urbanization and carbon dioxide emissions, two models are specified in line with Farhani & Ben Rejeb (2012) and Çetin & Ecevit (2015).

$$CO_{2it} = \beta_{0i} + \beta_1 FCE_{it} + \beta_2 UPO_{it} + \varepsilon_{it} \quad (1)$$

$$FCE_{it} = \beta_{0i} + \beta_3 UPO_{it} + \beta_4 CO_{2it} + \varepsilon_{it} \quad (2)$$

Where CO_2 denotes Carbon dioxide emissions per capita, FEC is the fossil fuel energy as percentage to total energy and UPO is the urban population as a percentage to total population. β_0 is the constant, ε_t, represents the error terms. β_1, β_2, β_3, and β_4 are the estimated coefficients of the independent variables. The subscript i and t denotes the country time period respectively.

3.3 Methods

The study employed panel cointegration and panel Granger causality to analyse the data. TheJohansen Fisher Panel Cointegration Test is applied to verify the presence of long run cointegrated relationship between carbon dioxide emissions (CO_2), energy consumption and urbanization. Fully modified OLS and Dynamic OLS are the useful to determine long run elasticity. Short run and long run dynamic causal relationship are estimated by panel vector error correction model (VECM) and Granger causality test.

4. Empirical results and discussions

4.1 Descriptive Statistics

Table 1: Descriptive statistics for the variables

Variables	Obs	Mean	Std.Dev.	Minimum	Maximum
Carbon dioxide	414	1.094206	1.686488	0.016313	8.568994
Energy consumption	453	32.36901	21.93466	1.639733	88.14867
Urbanization	460	43.60454	16.07194	14.927	90.092

Source: Author's computation. Using STATA version 16

The table 2 below present the correlation matrix of the variables under study. The results reveal that energy consumption and urban population have a positive and significant correlation with the dependent variable (carbon dioxide emissions). The correlation also reveals no evidence of multicollinearity problem is exist among the variables under study. Since none of the estimated coefficient of the independent variables is >0.75 using the cut off line set by Tabachnick and Fidell (2007).

Table 2: Correlation matrix of the variables

	CO_2	FEC	UPO
CO_2	1.0000		
FEC	0.6851	1.0000	
UPO	0.5404	0.4149	1.0000

Source: Author's computation. Using STATA version 16

Figure 1 shows a trend series between CO_2 emissions, energy consumption and the urban population of some selected countries in the Sub-Saharan Africa during the period under study. The trend indicates thatCongo Democratic Republic has the least amount of CO_2 emissions and energy consumption while South Africa happen to be the highest in term of energy consumption and emitting of carbon dioxide emissions.The countries that recorded the minimum and maximum urban population are Ethiopia and Gabon respectively.

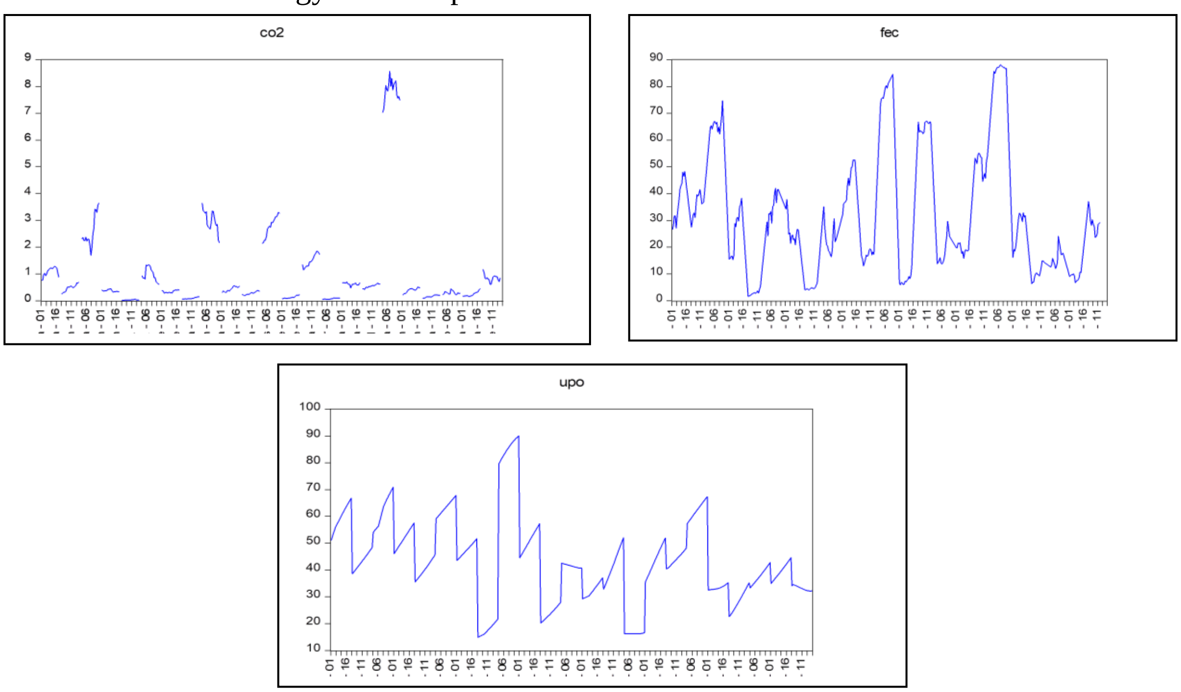

Figure 1: Trends in the Series

4.2 Unit root

The results of ADF and LLC tests are summarized in Table 3. The results indicate that the variables CO_2, FEC, and UPO are not stationary at level but stationary at first difference. All the three variables appear to be stationary at first difference at 5% significance level. This implies that the three variables contain a panel unit root and are integrated of same order I(1). And when the variables are integrated of same order, the panel cointegration tests can be applied to test the long run relationship between the variables.

Table 3: Panel Unit Root Test Results

	Level	**First difference**
ADF - Fisher Chi-square		
LCO_2	60.536	147.991***
	(0.1738)	(0.0000)
LFEC	9.1419	110.622***
	(1.0000)	(0.0000)
LUPO	58.6305	90.7293***
	(0.1002)	(0.0001)
Levin, Lin & Chu t*		
LCO_2	-0.3460	-11.2560***
	(0.3647)	(0.0000)
LFEC	4.9105	-6.5974***
	(1.0000)	(0.0000)
LUPO	5.1231	-14.8876***
	(1.0000)	(0.0000)

Notes: The panel unit root tests are conducted independently with trend and intercept; the optimal lag lengths are obtained automatically with the SIC. ***and ** indicates significance at 1% and 5% level respectively.

4.3 Cointegration Results

Table 4 shows the results of Johansen fisher cointegration test for the CO_2 and FCE models. It is observed that both the trace test and max-eigen test statistics cannot accept the null hypothesis of no cointegration (none, at most 1, and at most 2) at 1% significance level. These results reveal that there exists a long run cointegrated relationship between energy consumption, urbanization and CO_2 emissions in the sampled countries.

Table 4: Johansen Fisher Panel Cointegration Test

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	477.7***	0.0000	341.8***	0.0000
At most 1	176.6***	0.0000	135.4***	0.0000
At most 2	83.91***	0.0005	83.91***	0.0005

Notes: *** and ** indicates significance at 1% and 5% level respectively.

4.4 Panel Granger Causality Test

The results of the tests of cointegration reported in table 4 & 5 implies only the existence of long run and casual relationship, however it does not indicate the direction of casual relationship between the variables. In order to know the direction of causality, the panel-based on vector error correction model (VECM) followed by Wald test of coefficient developed by Engle and Granger (1987) are employed to examine the long-run and short-run dynamic casual relationships. The first step estimates the long-run parameters in Eq. (1), Eq. (2) and Eq. (3) in order to obtain the residuals corresponding to the deviation from equilibrium. The second step estimated the parameters related to the short-run adjustment. The resulting equations were used in conjunction with panel Granger causality testing are as follows:

$$\Delta CO2_{i,t} = \theta_{1,i} + \sum_{k=1}^{m} \theta_{1,1,i,k} \,.\, \Delta CO2_{i,t-k} + \sum_{k=1}^{m} \theta_{1,2,i,k} \,.\, \Delta FEC_{i,t-k} + \sum_{k=1}^{m} \theta_{1,3,i,k} \,.\, \Delta UPO_{i,t-k} + \delta_{1,i} . ECT_{i,t-1} + \mu_{1,i,t} \quad (1)$$

$$\Delta FCE_{i,t} = \theta_{2,i} + \sum_{k=1}^{m} \theta_{2,1,i,k} \,.\, \Delta CO2_{i,t-k} + \sum_{k=1}^{m} \theta_{2,2,i,k} \,.\, \Delta FCE_{i,t-k} + \sum_{k=1}^{m} \theta_{2,3,i,k} \,.\, \Delta UPO_{i,t-k} + \delta_{2,i} . ECT_{i,t-1} + \mu_{2,i,t} \quad (2)$$

$$\Delta UPO_{i,t} = \theta_{1,i} + \sum_{k=1}^{m} \theta_{3,1,i,k} \,.\, \Delta CO2_{i,t-k} + \sum_{k=1}^{m} \theta_{3,2,i,k} \,.\, \Delta FCE_{i,t-k} + \sum_{k=1}^{m} \theta_{3,3,i,k} \,.\, \Delta UPO_{i,t-k} + \delta_{3,i} . ECT_{i,t-1} + \mu_{3,i,t} \quad (3)$$

Where the term Δ denotes first difference; $\theta_{,i,k,t}$ (i=1, 2, 3) represent the country fixed effect; k (k=1,…,m) is the optimal lag length determined by the Schwarz Information Criterion; and $ECT_{i,t-1}$ is the estimated lagged error correction term derived from the long-run cointegrating relationship of Eq. (1), in which $ECT_{i,t} = CO2_{i,t} - \beta_i FEC_{i,t} - \beta_i UPO_{i,t}$.

Table 5: Panel Granger Causality Test Results (VECM)

Dependent Variable		Sourcesof causation (Independent variable)		
		Short run (t-statistic)		**Long run (t-statistic)**
	ΔLCO_2	ΔLFEC	ΔLUPO	ECT(-*1*)
ΔLCO_2	---	0.9562	1.9088	-0.0028**
ΔLFEC	6.3639**	-	0.7318	-0.0224***
ΔUPO	9.5112**	0.9264	-	-0.0251**

Notes:Figures denote F-statistic values. P-values are in parentheses. *** indicates significance at 1% level ** indicates significance at 5% level respectively. ECT indicates the estimated error-correction term.

The term, $\delta_{j,i}$ (i=1, 2,3) is the adjustment coefficient and $\mu_{j,i,t}$ is the disturbance term assumed to be uncorrelated with zero means.

The table 5 present the results of the panel vector error correction model (VECM). The result reveal that, based on error correction term *ECT (-1)* and Wald tests, there exists a bi-directional causality between energy consumption and CO_2emissions in the long run. The results also reveal that there exists long run unidirectional relationship from urbanizationto energy consumption. The finding also shows short run causality runs from CO_2 emissions to energy consumption and urbanization. These findings are consistent with Çetin & Ecevit (2015) for 19 Sub-Saharan Africa. In the short run no causality was found between energy consumption, urbanization and CO_2emissions. These results indicate that energy consumption and urbanization influence carbon dioxide emissions which in turn affect the quality of the environment.

Table 6: Granger Causality Test

Null Hypothesis	No. of Obs	F-Statistic (Prob.)	Prob.
FEC does not Granger Cause CO2 CO2 does not Granger Cause FEC	317	2.98722 (0.0192) ** 2.05431 (0.0867)	Rejected Accepted
UPO does not Granger Cause CO2 CO2 does not Granger Cause UPO	322	4.98187 (0.0007) ** 2.24586 (0.0640)	Rejected Accepted
UPO does not Granger Cause FEC FEC does not Granger Cause UPO	361	1.34952 (0.2512) 0.21280 (0.9313)	Accepted Accepted

** Implies rejection of null hypothesis at 5% level ofsignificance.

Source: E-views output, 2022

The results of the Granger causality test on table 6 above indicated that, a unidirectional causality runs from energy consumption (FEC) and urbanization (UPO) to carbon dioxide emissions (CO_2) at 5% level of significance at four lags.

In order to know the actual effect of energy consumption and urbanization on carbon dioxide, the study proceed to obtain the elasticity of energy consumption, urbanization to carbon dioxide emissions we applied FMOLS and DOLS and the results are reported in table 7. The results show that fossil fuel energy and urbanization do increase carbon dioxide emissions in the sample countries. That is to say, a 1% increase in fossil fuel energy and urbanization could lead to the increase of carbon dioxide emissions by 0.010%and 0.017%, 0.078% respectively. The results also indicate that, 1% increase in urbanization would decreaseCO_2 emissionsby0.018%. This result validates the findings of Dan'asabe, Mustapha & Tukur (2021)who used GMM in case of Sub-Saharan Africa.

Table 7. FMOLS and DOLS Results

Variables	FMOLS	DOLS
CO_2 emissions (Dependent variable)		
Energy consumption (LFEC)	0.0101***(0.0012)	0.0178*** (0.0016)
Urbanization (LUPOP)	-0.0183***(0.0033)	0.0785*** (0.0113)
Observations	386	371
R^2	-14.19	-36.80
Adjusted R^2	-15.20	-56.33

Notes ** and *** indicates significance levels of 5% and 1% respectively. Standard errors are in parenthesis.

Conclusion and policy recommendations

This study examined the links between energy consumption, urbanization and CO_2emissions in twenty-one Sub Saharan African economies using the data set from 2001 to 2020.The Cointegration test revealed that, there exists a long run relationship between energy consumption, urbanization, and CO_2emissions. The VECM Granger causality test revealed bi-directional Granger causality between the energy consumption and CO_2emissions in the long run. The study also found a uni-directional Granger causality test runs from urbanization to energy consumption in the long run. The results of the Granger causality test reveals, a unidirectional causality runs from energy consumption and urbanization to carbon dioxide emissions. The FMOLS and DOLS also confirmed that energy consumption and urbanization increased CO_2 emissions in SSA.

Based on the findings the study recommends that there is need to put in place well-articulated policies that can help reduce CO_2 emissions in SSA. For example, investment in cleaner energy such as biofuels and solar energy, and also implement policies that would promote rural development is necessary to curb the high rate of rural migration.

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