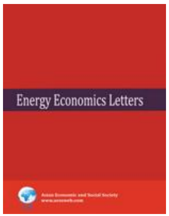
Energy Economics Letters, 2016, 3(1): 1-16

Energy Economics Letters
ISSN(e): 2308-2925

URL: www.aessweb.com



CARBON DIOXIDE EMISSIONS, URBANIZATION AND POPULATION: EMPIRICAL EVIDENCE IN SUB SAHARAN AFRICA

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ABSTRACT

Urbanization and population have been viewed as two of the major contributors to global CO_2 *emissions. This paper aims at examining empirically the relationship between urbanization, population and* CO_2 *emissions in 45 Sub-Saharan African (SSA) countries. This goal was achieved by using a panel data from 1990-2010 and the newly established pooled mean group (PMG) estimator for dynamic heterogeneous panels. This study is a contribution to the empirics of climate change which has been an ongoing debate over the past decades now. The study establishes that an increase in both urbanization and population significantly increases* CO_2 *emissions both in the long and short run. Furthermore, the study finds that,* CO_2 *emissions of countries with large population like Nigeria and Ethiopia tend to grow faster following energy consumption as compared to countries with small population like Cape Verde and Equatorial Guinea.*

Keywords: Urbanization, CO_2 emissions, Population, Pooled mean group estimator, SSA, Dynamic heterogeneous panels.

Contribution/ Originality

The study contributes to the existing literature and ongoing debate on climate change by using the newly developed heterogeneous panel cointegration techniques which have rarely been used to examine the impact of population and urbanization on CO_2 emissions of SSA countries.

1. INTRODUCTION

Globally, increases in carbon dioxide (CO_2) emissions have been of immense concern to countries worldwide over the past century. Currently, global climate change is one of humanity's greatest challenges. Global CO_2 emissions, especially from fossil fuel combustion continue to increase even though this increase has been decreasing recently. The world at large began to

DOI: 10.18488/journal.82/2016.3.1/82.1.1.16
ISSN(e): 2308-2925

experience global climate change issues during the 19th and 20th century when industrialized countries commenced the use of fossil fuels like oil and coal. Muller-Kuckelberg (2012) reports two main transformations in the use of energy among other things in which the beginning of global climate change issues can be traced back to. The first transformation been the replacement of waterpower with coal with the aim of increasing productivity during the nineteenth century and the second transformation been the use of oil to fuel engines of motor vehicles which occurred 150 years after the first transformation. These two factors among other things have contributed to an increase in global greenhouse gas emissions by a third from pre-industrial times to the twentieth century (Muller-Kuckelberg, 2012).

The focus at large when it comes to global anthropogenic CO_2 emissions has always been on the developed world and emerging economies in Asia because they jointly contribute to about 80% of the global anthropogenic CO_2 emissions. For instance, the top ten emitting countries in the world in the year 2012 which were all developed economies and emerging economies in Asia accounted for about two-thirds of the global anthropogenic CO_2 emissions (International Energy Agency, 2014). Africa as a continent during the period 1980-2005 accounted for only 2.5% of the global anthropogenic CO_2 emissions (Canadell *et al.*, 2009). Even though Sub-Saharan Africa's contribution to the global anthropogenic CO_2 emissions is smaller compared to continents like Asia and Europe, its contribution to global anthropogenic CO_2 emissions has been increasing. With the effects of rapid population growth on CO_2 emissions and the negative effects of increases in CO_2 emissions, this becomes more worrisome as SSA has one of the fastest population growth rates in the world. With one of the fastest population growth rates in the world coupled with a rising per capita GDP and pressures on land to meet food demands, it is expected that all other things being equal, its share of global anthropogenic CO_2 emissions over the coming decades will begin to increase although its share of emissions will still be low as compared to other continents like Europe and Asia. It is against this background that this study will seek to examine the effect of population and urbanization on CO_2 emissions as well as the determinants of CO_2 emissions in SSA.

Sub Saharan African (SSA) countries are mostly endowed with a wealth of natural resources and minerals such as gold, oil, forests and manganese. The development of this region is constrained by a lot of factors such as lack of proper health care, lack of, inadequate infrastructure, inadequate energy supply and constant depletion of natural resources such as forests. Agriculture is the main stay of the region having more variety of grains than anywhere in the world.

Even though SSA contributes the least to global anthropogenic CO_2 emissions as compared to other regions in the world, the Intergovernmental Panel on Climate Change (IPCC) reports SSA to be the most vulnerable region in the world to climate change. From a policy perspective, knowledge on the linkages between urbanization, population and CO_2 emissions in SSA will be key in designing and implementing proper environmental policies and mitigation strategies aimed at stabilizing greenhouse gas emissions in SSA. The study employs the newly developed heterogeneous panel cointegration techniques which have rarely been used to examine the impact of population and urbanization on CO_2 emissions of SSA countries. Most panel studies have employed the homogenous frameworks where the cointegrating vectors are assumed to be identical for all panel units. The employment of this new technique will bring to the forefront useful insights and results that will augment the existing panel studies literatures employed using the homogenous frameworks. Furthermore, my literature search suggests that only Alagidede *et al.* (2014) has employed the newly developed heterogeneous panel cointegration to examine climate change related issues in SSA but this study differs from their work. Whereas Alagidede *et al.* (2014) examined the effect of climate change on economic growth in SSA, this study will examine the effect of population and urbanization on CO_2 emissions in SSA.

2. LITERATURE REVIEW

Quite a number of studies that have examined CO_2 emissions-population growth nexus holds that population growth has played a role in increasing CO_2 emissions globally. Some studies have examined the channels through which population growth contributes to increases in CO_2 emissions. Mention can be made of Birdsall (1992) where the study outlines two channels through which population growth contributes to CO_2 emissions. The first channel is through its effect on energy consumption where a large population could result in increased demand for energy for power which leads to an increase in CO_2 emissions. The second channel is through its effect on deforestation where increasing population tend to destroy the forests and engage in combustion of fossil fuels contributing to the release of CO_2 emissions. Population has also been found to contribute to CO_2 emissions through its effect on production and consumption activities (Satterthwaite, 2009). Some studies have also focused on the nature of relationship between population growth and CO_2 emissions employing different methodologies and different kinds of data. It should be noted that a large proportion of studies admit a positive relationship between population growth and CO_2 emissions (Shi, 2003; Cole and Neumayer, 2004; Morales-Lage *et al.*, 2006; Muhammad *et al.*, 2011; Hossain, 2012). A few of the studies considered population density instead of population growth (Panayotou, 1993; Nguyen, 1999; Panayotou, 2000; Muhammad *et al.*, 2011).

Some researchers have also attributed the increase in CO_2 emissions globally to urbanization. Zhu and Peng (2012) explains three different ways through which urbanization affects CO_2 emissions. First, urbanization increases residential consumption and energy demand as cities tend to make use of a lot of energy thereby increasing CO_2 emissions. Second, urbanization tends to increase demand for houses which also increases demand for housing materials such as cement which is an important source of CO_2 emissions. Thirdly, the increase in the demand for houses require the clearing of trees and grasslands conversion which releases the carbon stored in the trees increasing CO_2 emissions. Studies on the impact of urbanization on CO_2 emissions have not quite been intensively explored especially in SSA. A balanced panel study by Poumanyvong and Kaneko (2010) covering the period 1975-2005 and considering different development stages found urbanization to positively affect CO_2 emissions for all income groups. The positive association between urbanization and CO_2 emissions found by Poumanyvong and Kaneko (2010) is also confirmed by a number of studies (Cole and Neumayer, 2004; Liddle and Lung, 2010).

3. DATA AND METHODOLOGY

3.1. Data

The study relied on a panel data set on 45 SSA countries[1] spanning from 1990-2010. The data was obtained solely from the World Development Indicators. Countries were selected solely based on the availability of data, particularly based on the data on CO_2 emissions, urbanization and population.

Table-1. Summary Statistics of variables

Variable	Obs	Mean	Std. Dev.	Min	Max
CO_2	896	12,561.80	57363.54	7.334000	499016.4
ENERGY	439	26.37441	20.41237	2.697037	87.82350
TRADE	909	0.717317	0.381863	0.000000	2.752324
POP	945	14592601	22167671	70000	1.58E+08
Y	942	953.0944	1517.318	54.50519	8787.766
POPY	942	7.94E+09	2.19E+10	0.00000	1.88E+11
POPENERGY	439	2.52E+08	6.46E+08	0.00000	4.33E+09
URB	945	4762776	8966752	34487.60	77628943
URBENERGY	439	1.12E+08	3.47E+08	0.00000	2.67E+09
URBY	942	3.54E+09	1.25E+10	0.00000	1.15E+11

Source: Author's Estimations using Eviews 9.5

The total number of observations for each of the variables used in this study are reported in the second column of Table 1 which clearly indicates the maximum and minimum number of observations to be 945 and 439 respectively. The mean real GDP per capita for the 45 sampled countries over the study period is US$953.0944 confirming the low income levels of many countries in the sub Saharan African region. Urban population averaged 4,762,776 within the study period with the maximum and minimum urban population recorded at 77,628,943 and 34487.60 respectively. The standard deviation confirms there exist a significant variability in the urban

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[1] Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroun, Cape Verde, Central African Republic, Chad, Comoros, Congo Republic, Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Republic Democratic of Congo, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

population of these countries. This can also be said of the population variable as the standard deviation of population shows a wide variability in the total population of these sampled countries. CO_2 emissions measured in kilotons averaged 12,561.80 with the maximum and minimum CO_2 emissions being 499016.4 and 7.334000 indicating a large disparities of CO_2 emissions among the sampled countries.

3.2. Empirical Model

The study adopts a baseline model which is specified to reflect the effect of economic growth, population and other control variables on CO_2 emissions. The following empirical model is employed;

$$In(CO_2)_{it=}\beta_0+\beta_1 InURB_{it}+\beta_2 InPOP_{it}+\beta_3 InTRADE_{it}+\beta_4 InENERGY_{it}+\beta_5 InPOPENERGY_{it}+\beta_6 In(CO_2)_{i,t-1}+\beta_7 InY_{it}$$
$$+\beta_8 InURBY_{it}+\beta_9 URBENERGY_{it}+\beta_{10} POPY_{it}+\varepsilon_{it}\text{...}(1)$$

Where In represents the natural logarithm; CO_{2it} represents Carbon dioxide emissions at time t measured in kilotons; Y_{it} is real output (proxied by real GDP per capita); POP denotes Total Population; TRADE denotes the level of trade openness in the economy (proxied by the ratio of the sum of imports and exports to GDP); ENERGY denotes energy consumption (proxied by fossil fuel energy consumption as a percentage of total energy consumption); POP denotes total population; URB denotes urbanization (proxied by total urban population); POPENERGY and URBENERGY are interaction terms between population and energy consumption and urbanization and energy consumption respectively ; $(CO_2)_{t-1}$ represents Carbon dioxide emissions in the previous period; URBY and POPY are also interaction terms between urban population and real output and population and real output respectively; *i* is the country; *t* is the time; ε is the disturbance term. POPENERGY and URBENERGY are included because according to Birdsall (1992) a large population could result in increased demand for energy increasing CO_2 emissions. URBY and POPY are included in the model because according to Satterthwaite (2009) urbanization is driven by increases in growth especially in countries where a large proportion of the growth comes from production in industry and services sector which are mostly located in the urban areas.

In terms of a priori expectations, the literature predicts a positive relationship between population, energy consumption, urbanization and CO_2 emissions but the relationship between CO_2 emissions and variables such as economic growth and international trade could either be positive or negative. My literature search suggests that this is the first study to include an interaction term between population and energy consumption and urbanization and energy consumption as well as real output and urbanization and real output and population. Notwithstanding that, the study predicts a positive relationship between these interaction terms and CO_2 emissions.

3.3. Estimation Technique

To investigate the existence of a long run equilibrium relationship between CO_2 emissions and the regressors, the study would employ the newly established pooled mean group (PMG) estimator for dynamic heterogeneous panels developed by Pesaran and Shin (1999). This is a panel version of the Auto regressive distributed Lag (ARDL) Bounds testing approach. With a large time series (T) and cross sectional units (N), the usual practice is to employ the Mean Group (MG) estimator which estimates N separate regressions and further computes the coefficient means or to employ the dynamic fixed-effects (DFE) which pools the data and assumes equal slope coefficients and error variances. The PMG is seen as an intermediate procedure between the MG estimator and DFE because it involves averaging (representing the MG estimator) and pooling (representing the DFE). The PMG estimator allows the short run coefficients and the error variances differ across groups but the long run coefficients are constrained to be identical.

The cointegration analysis in panel data setting is similar to the way cointegration analysis is carried out in time series data setting by first; testing for the presence of a long run relationship between the variables (testing for cointegration); estimating the long run coefficients of the variables and lastly; estimating the short run coefficients of the variables. The ARDL approach was used because of its advantages such as the involvement of just a single equation set-up making it easier and simpler to interpret compared to other conventional techniques such as the Engel Granger two-step residual-based procedure, Johansen system-based reduced rank regression approach and variable addition by Park (1990) etc., which involves several equation set-up. According to Afzal *et al.* (2010) the ARDL Approach produces unbiased and efficient estimates because it is able to avoid the problems of serial correlation and endogeneity. This approach can be applied to a mixture of I (0) and I (1) regressors.

3.3.1. Estimation of the Long-Run Relationship

Estimation of the long-run relationship between the variables is premise on the existence of a cointegrating relationship between the non-stationary variables. Pesaran and Shin (1999) suggest a (maximum-likelihood) pooled mean group (PMG) estimator for dynamic heterogeneous panels which fits an ARDL model to the data. This can further be specified as an error correction equation to enhance economic interpretation.

An Error Correction Model (ECM) of an ARDL (*p, q, q… q)* specification can be considered as shown in equation (2) below;

$$\Delta(CO_2)_{it} = \varphi(CO_2)_{i,t-1} + \alpha' X_{i,t-1} + \sum_{j=1}^{p-1}\lambda_{i,j}\Delta(CO_2)_{i,t-j} + \sum_{j=0}^{q-1}\delta_{ij}\Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \ldots (2)$$

where X is a vector of explanatory variables; $\alpha^{'}$ contains the long run dynamics; φ is the error correction term, and δ_{ij} contains the short run dynamics.

4. RESULTS AND DISCUSSION

This section presents the results and discussions of the estimated relationship between CO_2 emissions, urbanization and population in SSA. Economic theory suggest that time series data especially macroeconomic variables that span over a long period of time often tend to exhibit some mean reverting behavior, hence the need to undertake stationarity tests, to ascertain the panel unit root properties of the series.

4.1. Panel Unit Root Tests Results

This study employs five different panel unit root tests namely; Levin-Lin-Chu's (LLC) t^{*}, Breitung's t, Hadri's Z, Im-Pesaran-Shin's (IPS) W, and ADF-Fisher χ^2 tests. LLC, Breitung and Hadri's unit root tests are based on the assumption of common unit root process that the autocorrelation coefficients of the variables been tested across cross-sections are identical. On the other hand, the IPS and ADF-Fisher χ^2 tests are based on the assumption of individual unit root process that the autocorrelation coefficients of the variables been tested across cross-sections vary. One of the advantages of using panel-based unit toot tests is the fact that, because panel data pools both cross-sections and time series, panel-based unit toot tests improves extremely the tests' finite sample power as compared to the conventional unit root tests for time series. This advantage is confirmed by studies such as Im *et al.* (2003) and Levine *et al.* (2002) in which the study found a tremendous improvement in the power of unit root tests when using panel data.

The test results from tables 2 show evidence of non-stationary in most the variables used in this study. The Breitung's t test and the Hadri's Z test provide strong evidence of non-stationarity in all the variables. The IPS and ADF tests indicate that with the exception of population, trade and urbanization, all the other variables are not stationary. Stationary tests are then carried out at first difference for variables that were not stationary at levels with the results shown in table 3.

Table-2. Panel unit root test results (at levels)

Tests assuming a common unit root process				**Tests assuming individual unit root process**	
Series Name	LLC t^*-stat:	Breitung t-stat:	Hadri Z-stat	IPS W-t-bar stat:	ADF-Fisher X^2
	H_0: Unit root	H_0: Unit root	$H_{0:}$ No Unit root	H_0: Unit root	H_0: Unit root
INCO$_2$	-1.32376 [0.0928]	-0.32176 [0.3738]	10.9018 [0.0000]	0.56682 [0.7146]	83.0358 [0.6855]
INENERGY	-1.08149 [0.1397]	-0.28923 [0.3862]	8.95632 [0.0000]	-0.69015 [0.2450]	52.7362 [0.1239]
INY	-4.49010 [0.0000]	8.47967 [1.0000]	10.4455 [0.0000]	0.30041 [0.6181]	100.365 [0.2136]
INPOP	-10.0939 [0.0000]	24.4272 [1.0000]	11.3472 [0.0000]	-2.17183 [0.0149]	273.776 [0.0000]
INTRADE	-5.70657 [0.0000]	-0.44726 [0.3273]	12.2402 [0.0000]	-3.41309 [0.0003]	150.654 [0.0001]
INURB	-19.6589 [0.0000]	21.1978 [1.0000]	11.9132 [0.0000]	-5.64506 [0.0000]	314.030 [0.0000]
INPOPENERGY	-2.70228	0.07428	9.09534	-0.23097	50.9045
	[0.0034]	[0.5296]	[0.0000]	[0.4087]	[0.1631]
INURBENERGY	-2.70747	0.27868	9.12349	0.25143	45.8453
	[0.0034]	[0.6098]	[0.0000]	[0.55993]	[0.3157]
INURBY	-2.96933	8.81095	9.91261	2.11350	78.4032
	[0.0015]	[1.0000]	[0.0000]	[0.9827]	[0.8035]
INPOPY	-2.96933	8.81095	9.91261	2.11350	78.4032
	[0.0015]	[1.0000]	[0.0000]	[0.9827]	[0.8035]

Source: Author's Estimations using Eviews 9.5

Table-3. Panel unit root test results (at first difference)

Tests assuming a common unit root process				**Tests assuming individual unit root process**	
Series Name	LLC t^*-stat:	Breitung t-stat:	Hadri Z-stat	IPS W-t-bar stat:	ADF-Fisher X^2
	H_0: Unit root	H_0: Unit root	$H_{0:}$ No Unit root	H_0: Unit root	H_0: Unit root
INCO$_2$	-12.3665 [0.0000]	-7.69728 [0.0000]	12.4722 [0.0000]	-7.54630 [0.0000]	210.600 [0.000]
INENERGY	-9.91525 [0.0000]	-6.99026 [0.0000]	4.54524 [0.0000]	-8.47851 [0.0000]	146.875 [0.0000]
INPOPENERGY	-10.0533	-6.75284	4.15824	-8.67461	149.252
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
INURBENERGY	-10.0582	-6.73949	4.26794	-8.72585	150.094
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]

Source: Author's Estimations using Eviews 9.5

4.2. Panel Cointegration Results

Table 4 presents two variants of panel cointegration in this study namely the Pedroni cointegration test and the Kao's residual cointegration test. A cointegration found among the variables will imply an existence of a long run relationship between the variables. The Pedroni and Kao cointegration tests automatically set the lag length using the Schwartz Bayesian Information Criterion (SIC). The Pedroni and Kao cointegration tests are based on long run residuals resulting from estimating long run static regression. Hence, the null hypothesis of no cointegration is tested with the results shown in table 4.

The results from the Pedroni cointegration test if the assumption of common autoregressive coefficients holds do not provide any support for the existence of cointegration among the variables. However, when we assume between-dimensions (individual autoregressive coefficients), the results show some evidence of cointegration among the variables as depicted by the rejection of the null hypothesis of no cointegration at 1% level of significance of Group PP and Group ADF. The existence of cointegration using the assumption of between-dimensions (individual autoregressive coefficients) in the Pedroni test is confirmed by the Kao's test which also rejects the null hypothesis of no cointegration at 1% level of significance.

Table-4. Panel Cointegration test results

Pedroni cointegration test [a]***Common AR coefficients (within dimension)***				
	Statistic	p-value	Weighted Statistic	p-value
Panel v	-1.259475	0.8961	-0.702347	0.7588
Panel rho	0.209871	0.5831	0.167814	0.5666
Panel PP	-3.855908	0.0001	-3.745304	0.0001
Panel ADF	-3.642250	0.0001	-3.595750	0.0002
[a]*Individual AR coefficients(between dimension)*				
Group rho	0.727842	0.7666		
Group PP	-4.577807***	0.0000		
Group ADF	-4.452460***	0.0000		
[b]Kao residual cointegration test				
Test Statistic= -3.017585 (0.0013)				

Source: Author's Estimation using Eviews 9.5. *** indicates significance at 1% level of significance.

4.3. Estimation and Interpretation of Long-Run and Short-Run Relationships

The short and long-run estimates based on PMG estimation are reported in each column of Table 5. The table also presents five alternative models. In models 1-4, the results of variables accounting for one interaction term at a time are reported. This is because some of the variables were found to be highly correlated (see Appendix 1) and hence including them in the same model leads to unbiased and inconsistent estimates.

Table-5. Short and Long-run estimation results (PMG Estimation Results)

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Convergence coefficients	-0.6620*** (0.0933)	-0.5612*** (0.0592)	-0.5738*** (0.0801)	-0.5586*** (0.0586)	-0.662*** (0.0933)
Long-run coefficients					
INENERGY	0.8076*** (0.0340)	0.7604*** (0.0403)	0.0410 (0.0589)	0.0079 (0.8935)	0.8076*** (0.0340)
INY	-0.59748** (0.2669)		0.1316*** (0.0435)	0.0678 (0.0602)	0.1648*** (0.0411)
INPOP		0.6626*** (0.1144)			0.7623*** (0.2525)
INTRADE	0.04307* (0.0230)	0.1138*** (0.0305)		0.1265*** (0.0297	0.0431* (0.0230)
INPOPENERGY				0.7615*** (0.0668)	
INPOPY	0.762312*** (0.2525)				
INURBY		0.0985 (0.0604)			
INURBENERGY			0.7472*** (0.0476)		
INURB	0.20444*** (0.1892)				0.2044 (0.1892)
ΔINENERGY	0.1393 (0.1699)	0.3321** (0.1447)	-9.4437** (4.3206)	-17.736*** (5.8077)	
ΔINY	-35.2770 (23.8273)		0.6446* (0.3540)	0.7076* (0.3830)	
ΔINPOP		17.5353*** (5.7828)			
ΔINTRADE	0.02363 (0.0499)	0.0117 (0.0494)		0.0026 (0.0478)	
ΔINPOPENERGY				18.0581*** (5.777)	
ΔINPOPY	36.1215 (24.1300)				
ΔINURBY		0.7926** (0.3741)			
ΔINURBENERGY			9.7478** (4.2754)		
ΔINURB	-6.4369 (18.7480)				
No. of Countries	45	45	45	45	45
No. of observation	945	945	945	945	945

Source: Authors Estimation using Eviews 9.5. $^{*, **, ***}$ indicates significance at 10%, 5% and 1% level of significance. All equations include a constant country-specific term. Values in ( ) are standard errors.

4.3.1. Long-Run Elasticities

The results of the five models for both short and long run generally show consistency in terms of the signs but not of statistical significance. It should also be noted that all coefficients are interpreted as elasticities. Trade openness, energy consumption and real output was found to be a long run drivers of CO_2 emissions in at least three of the five models. With the exception of the sign of the coefficient of real output, which turned negative in model 1, all the other signs of the coefficient of all other variables were consistent in all 5 models.

Population and Urbanization have their expected theoretical signs in the long run. Specifically, a one percent increase in total population increases CO_2 emissions by 0.6626% and 0.7623% in models two and five respectively and vice versa all other variables constant. Also, a one percent increase in urbanization increases CO_2 emissions by 0.2044% and vice versa all other variables constant. This result is not surprising as majority of people in SSA depend on biomass as their primary energy. Also, with a current annual population growth rate of 2.74% and with Africa projected to record the largest population growth over the next 40 years, CO_2 emissions is bound to increase with population. Also, available data shows Africa has experienced the highest urban population growth during the last two decades at 3.5% per year with this growth rate expected to hold into 2050. It is also estimated that by the year 2030, 50% of Africans will live in the cities. This trend has implications for increases in CO_2 emissions in the long run.

The long run results also show that energy consumption and CO_2 emissions are positively and significantly related. Specifically, a one percent increase in energy consumption leads to an expected increase in CO_2 emissions by 0.8076%, 0.7604%, and 0.8076% in models 1,2 and 5 respectively all other variables constant. This finding is consistent with Abimbola and Bello (2010); Muhammad *et al.* (2011); Saboori and Soleymani (2011) and Hossain (2012). Biomass accounts for about 50% of SSA total energy consumption and its combustion leads to increases in CO_2 emissions. Also, demand for biomass energy is a major cause of deforestation and forest degradation which leads to increases in CO_2 emissions as these tress and forests serve as a form of carbon sink. Trade openness was also found to be positive and statistically significant in the long run and in all four models that were used in the estimation. Specifically, a one percent increase in trade openness causes CO_2 emissions to increase by 0.04307%, 0.1138%, 0.1265% and 0.0431% in models 1, 2, 4 and 5 respectively all other variables constant. Evidently, the excessive use of fossil fuels such as oil which is a major component of imports, increased importation of e-waste which are disposed of through burning and the increase production and export of gold which uses a lot of petroleum products for power generation tends to increase CO_2 emissions. These are some of the possible factors accounting for the detrimental effect of trade liberalization on CO_2 emissions in SSA.

The interaction terms of population and energy consumption as well as urbanization and energy consumption had their expected signs. The positive and significant interaction term of population and energy consumption implies that CO_2 emissions of countries with large population like Nigeria and Ethiopia tend to grow faster following energy consumption as compared to countries with small population like Cape Verde and Equatorial Guinea. This results tend to support the assertion by Birdsall (1992) that population contributes to CO_2 emissions through its effect on energy consumption where a large population could result in increased demand for energy for power which leads to an increase in CO_2 emissions. Also, the interaction term of urbanization and energy consumption has a similar sign and statistical significance as the interaction term of population and energy consumption. One of the major drivers of the use and demand for biomass in SSA is the rapid urbanization with the excessive use of biomass known to contribute to CO_2 emissions. This result is consonance with Zhu and Peng (2012) where urbanization increases residential consumption and energy demand as cities tend to make use of a lot of energy thereby increasing CO_2 emissions.

Even though the interaction term of urbanization and real output had its expected sign, it was found to be statistically insignificant. However, the coefficient of the interaction term of population and real output was found to be positive and statistically significant at 1% level of significance. Specifically, CO_2 emissions of countries with large population tend to grow faster following real output as compared to countries with small population.

4.3.2. Short-Run Elasticities

The results in model 5 do not account for all the four interaction terms used in this study. However, in all the five models, the error correction terms as expected are consistently, negative and statistically significant. The negative and statistically significant term of the error term confirms the conclusion of cointegration between the variables. The error correction terms of -0.6620, -0.5612, -0.5738, -0.5586 and -0.662 suggests that when CO_2 emissions are above or below its equilibrium level, it adjusts by almost 66.20%, 56.12%, 57.38%, 55.86% and 66.2% in models 1, 2, 3, 4 and 5 respectively.

The interaction term of urbanization and real output was found to be positive and statistically significant at 5% level of significance in the short run. Specifically, CO_2 emissions of countries with large population tend to grow faster following real output as compared to countries with small population in the short run. This results support the assertion by Satterthwaite (2009) that, urbanization is driven by increases in growth especially in countries where a large proportion of the growth comes from production in industry and services sector which are mostly located in the urban areas. Other variables also found to be statistically significant in the long run include total population, energy consumption, interaction terms of urbanization and energy consumption and population and energy consumption.

5. CONCLUSION AND RECOMMENDATIONS

This study aimed at examining empirically the relationship between urbanization, population and CO_2 emissions in 45 SSA countries. This goal was achieved by using a panel data from 1990-2010 and the newly established pooled mean group (PMG) estimator for dynamic heterogeneous panels developed by Pesaran and Shin (1999). An important part of this study is the addition of some key interaction terms that might explain further the linkages between these variables.

The study found trade openness, energy consumption, population, urbanization and real output to be a long run drivers of CO_2 emissions in at least three of the five models. With regards to the interaction terms that were added to four of the five models, the interaction terms of population and energy consumption as well as urbanization and energy consumption were positive and statistically significant. On the other hand, the study found population, energy consumption, interaction terms of urbanization and energy consumption and population and energy consumption to be the short run drivers of CO_2 emissions in SSA.

Energy consumption was found to have a significantly positive impact on CO_2 emissions both in the long run and short run indicating that investments in cleaner energy alternative such as biofuels, biogas, solar and the implementation of energy efficiency programmes could help reduce CO_2 emissions. In general, the study recommends SSA countries to pursue Low Carbon Development Strategy (LCDS) which integrates development and climate change mitigation actions as elaborated in COP 15 if country's' international commitments to climate change mitigation are to be achieved.

The major findings of this paper are in consonance with the assertion that population and urbanization are two of the major driving forces behind increasing CO_2 emissions in SSA over the past two decades. The study recommends policy makers to take into consideration the dynamics of population and urbanization when negotiating international, regional and local agreements with regards to climate change. SSA countries should also aim at controlling the rate of population growth through intervention programs such as improving girl child's education, women empowerment and creating the awareness to educate people on the negative effects of having large family size not only on the environment but also on the socioeconomic aspects such as health, education and standards and costs of living.

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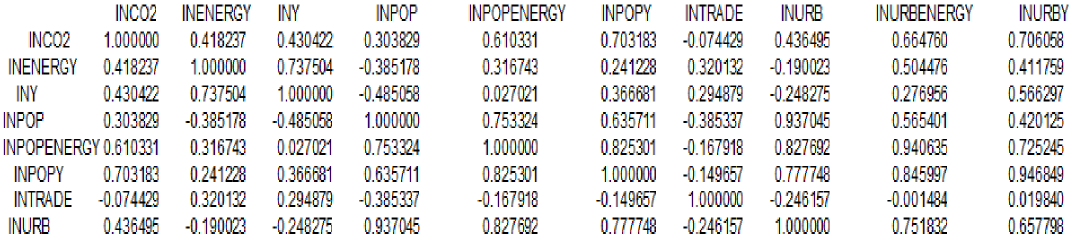
Appendix-1. Correlation Matrix of Variables



	INCO2	INENERGY	INY	INPOP	INPOPENERGY	INPOPY	INTRADE	INURB	INURBENERGY	INURBY
INCO2	1.000000	0.418237	0.430422	0.303829	0.610331	0.703183	-0.074429	0.436495	0.664760	0.706058
INENERGY	0.418237	1.000000	0.737504	-0.385178	0.316743	0.241228	0.320132	-0.190023	0.504476	0.411759
INY	0.430422	0.737504	1.000000	-0.485058	0.027021	0.366681	0.294879	-0.248275	0.276956	0.566297
INPOP	0.303829	-0.385178	-0.485058	1.000000	0.753324	0.635711	-0.385337	0.937045	0.565401	0.420125
INPOPENERGY	0.610331	0.316743	0.027021	0.753324	1.000000	0.825301	-0.167918	0.827692	0.940635	0.725245
INPOPY	0.703183	0.241228	0.366681	0.635711	0.825301	1.000000	-0.149657	0.777748	0.845997	0.946849
INTRADE	-0.074429	0.320132	0.294879	-0.385337	-0.167918	-0.149657	1.000000	-0.246157	-0.001484	0.019840
INURB	0.436495	-0.190023	-0.248275	0.937045	0.827692	0.777748	-0.246157	1.000000	0.751832	0.657798