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Dynamic Impact of Income Inequality on Carbon Dioxide Emissions in Africa: New Evidence from Heterogeneous Panel Data Analysis

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ABSTRACT

We extended the study of Zhang and Zhao (2014) for China, which examines the regional impact of carbon dioxide emissions on income inequality. The present article examine the dynamic impact of income inequality on carbon dioxide emissions in Africa. We applied heterogeneous panel autoregressive distributed lag techniques of mean group (MG) and pooled MG suggested by Pesaran et al. (1999), during 1984-2001. The main empirical result reveals that; the relationship between income inequality and carbon dioxide emissions is negative and statistically significant. This means that; widening income inequality could lead to the reduction of carbon dioxide emissions in the sampled countries. Moreover, the variables of trade openness, per-capita gross domestic product (GDP), and urbanization are positive and statistically significant; this means that increase in any of these variables could lead to overall increase in the level of carbon dioxide emissions. Therefore, in providing policies that will be used to improve environmental quality in Africa, income inequality should not be considered because it is reducing the level of environmental degradation through reduction of carbon dioxide emissions. Hence, policy makers should not consider income inequality when formulating environmental policies among the selected sample countries.

Keywords: Income Inequality, CO_2 Emissions, Mean Group, Pooled Mean Group, Panel Autoregressive Distributed Lag, Africa
JEL Classifications: F64, Q54, Q58

1. INTRODUCTION

The level of poverty in the global economy is among the most pressing, disturbing, and challenging issues that need serious attention from governments, institutions, and global economic agencies like the World Bank, International Monetary Fund, and United Nations (UN), etc. This is due to its detrimental effects of reducing productivity and increasing social problems that affects the wellbeing of the people and ultimately affects the entire economy. Although, the Africa's fossil fuel CO_2 emissions is considered low both in per-capita and absolute terms. But still the overall emissions has substantially grown in the region. The liquid and solid fuels accounted for about 35% and gas contributed to 16.9% of the overall regional amount. The number of countries that contributes to higher emissions from fossil fuels and cement productions is six (6), because South Africa alone account for 38% of the continental aggregate. The remaining 46% comes from Egypt, Algeria, Nigeria, Libya and Morocco (Boden et al. 2011).

One of the main objectives of sustainable development goals (SDGs) is to "plan of action for people, planet and prosperity." This plan of action contains 17 different goals two of which are the issues of energy and poverty reduction in the world. Goal 10 in the SDGs has the objective of "Reduce Inequality Within and Among Countries," Its main target is that, "By 2030, progressively achieve and sustain income growth of the bottom 40% of the population at a rate higher than the national average." Table 1 shows the level of income inequality in Africa when compared with other fellow developing countries, the mean and median income inequality surpass that of other developing countries which shows how broad the income disparity is in the continent. When the level of country's income is considered, countries in Africa are still leading in terms of unequal distribution of income this might be among the reasons of excessive poverty in the region. Brookings (2016) states more details about income inequality in Africa, and other countries.

The Figure 1 shows the African map which indicate the location of the continent in the globe and the countries.

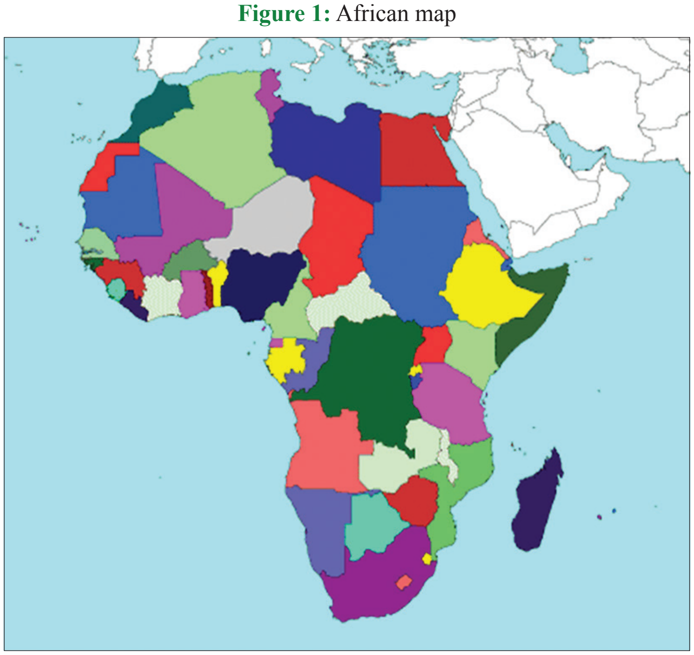
The objective of this paper is to examine the dynamic impact of income inequality on carbon dioxide emissions in selected African countries during 1984-2001. We control the model with variables of trade openness, per-capita gross domestic product (GDP), and urbanization. Heterogeneous panel estimation techniques of dynamic fixed effect (DFE), MG and PMG are applied in order to achieve the stated objective. This study is different from the existing literature in three folds; first, most of the studies that relate carbon dioxide emissions with the income inequality are mainly a single country study e.g. Wang et al. (2012), Zhang and Zhao (2014). Our study used panel data analysis that comprises of various African countries, hence the finding is expected to be more informative. Secondly; to our knowledge presently, no single study that examine this relationship among African countries. Thirdly, we filled the methodological gap by applying heterogeneous panel autoregressive distributed lag (ARDL) technique that is mainly scarce in this particular issue in the existing literature. The rest of the paper is organized as follows; section two deals with literature review. Section three highlights the econometric models and methodology, section four explained the data, its sources and measurements of the variables. Section five discussed the empirical findings, and lastly section six concludes and proposes policy recommendations for the policy makers based on the findings of the study.

Table 1: Inequality in Africa relative to other developing economies

Gini	Africa	Other developing countries
Mean	0.43	0.39
Median	0.41	0.38
Ratio of incomes: Top 20%/Bottom 20%	10.18	8.91
Low-income	0.42	0.39
Lower-middle-income	0.44	0.40
Upper-middle-income	0.46	0.40

Source: WIDER inequality database, 2014; World development indicators, 2014

Figure 1: African map



2. LITERATURE REVIEW

The relationship between income inequality and carbon dioxide emissions is not highly examine in the literature. Therefore, we review both direct and related literatures on the issue. For example, Ravallion et al. (2000), in their study on the nexus between income inequality and carbon dioxide emissions found that; distribution of income is among the determinant factors that affect carbon emissions, hence lead to global warming in the economies. Higher income inequality is associated with lower carbon dioxide emissions both between and within countries for a given average of income level. They also corroborate that; higher growth of the economy is attached with more carbon emissions. Hence, a tradeoff exist between climate control and economic growth. Sharmin and Khan examine the causal relationships between energy consumption, income and energy prices for the African countries using Johansen's maximum-likelihood test of cointegration and error-correction model (ECM). To have a reliable estimate, only countries having data availability for a minimum period of 25 years were considered. This requirement reduces the sample size to 26 countries only. Out of these, a long run cointegrating relationship was found for a total of six countries, which was then subsequently analyzed to confer on the direction of causality. Out of the reported five countries, they found the existence of bidirectional Granger causality for Ethiopia, Morocco and Mozambique. The result for Angola suggests unidirectional Granger causality running from income to energy consumption while no Granger causality for the case of Tanzania.

Coondoo and Dinda (2008), examined the relationship between the inter-country income inequality, CO_2 emissions and temporal shifts. The study also assess the per-capita mean of CO_2 emissions and its distributional inequality in line with the corresponding mean and the distributional inequality of income. They applied Johansen cointegration technique and found that; inter-country income inequality has substantial effect on the level of the emissions for most of the countries investigated. Akbostanc et al. (2009), examined the impact of income on environmental quality in Turkey based on time series and panel data techniques that covers 58 provinces in the country during 1968-2003 and 1992-2001 respectively. The paper is of two stages; first stage assess the impact of per-capita income on carbon dioxide emissions and the second segment examine the impact of income on air pollution respectively. The empirical finding based on the time series show that; there is a positive and significant relationship between carbon dioxide emissions and income in the long-run. The panel data aspect however reveals N-shape relationship between SO_2 and PM10 emissions in the provinces. Hence, the time series result of this study disprove EKC hypothesis.

Clarke-Sather et al. (2011), assess the distribution of carbon dioxide emissions across Chinese provinces based on common measures of income inequality of coefficient of variation, Gini Index, and Theil Index. They apply IPCC reference approach during 1997-2007. Carbon dioxide emissions inequality is decomposed into inter-regional and intra-regional mechanisms. The result show that, the pattern of carbon dioxide emissions inequality in China is closely related although slightly lower than the per-capita income inequality. While, when the inequalities are decomposed it shows a different pattern. However, the nature of inter-provincial income inequality is regional in nature and inter-provincial carbon dioxide emissions inequality is basically intra- regional. Sharma (2011), assess the factors that influence carbon dioxide emissions across a panel of 69 countries. The analysis is based on three income categories of high income, middle income, and low income during 1985-2005. They found that; trade openness, GDP per capita (GDPC), and energy consumption have a positive and significant effect on CO_2 emissions. However, urbanization has a negative and significant impact on CO_2 emissions for both income levels. For the global panel, they found that only GDPC and total primary energy consumption are statistically significant determinant of CO_2 emissions, while urbanization, trade openness, and GDPC negatively influences CO_2 emissions.

Bouvier (2014), used a data from Risk-Screening Environmental Indicators model and the United States Census Bureau, and examine the block-group distribution of environmental risk and income of Maine State of the United States. The outcome reveals that, there is unequal distribution between toxic air emissions and income in the state, and the inequality is still strengthening. This means that toxic emissions is shared more in the State than income. Zhang and Zhao (2014), in their study examine the impact of income inequality on carbon dioxide emissions during 1995-2010 at both regional and national level in China. The key finding suggest that; increase in the level of income lead to a higher carbon dioxide emissions in China, this means higher income deteriorate environmental quality. The impact is not happen to be the same based on the regional analysis, as the impact is much higher in the Eastern region than the Western region of the country. This result shows that reducing the wide income variation may control carbon dioxide emissions in the country.

Shahbaz et al. (2014) examine the relationship between economic growth, electricity consumption, urbanization and environmental degradation during 1975-2011 in United Arab Emirates. The finding based on ARDL bounds and VECM Granger causality are used to test the long-run and short run relationship of the variables. The main result shows an inverted U-shaped relationship between economic growth and CO_2 emissions, i.e., economic growth increases energy emissions at the initial stage and falls after a threshold point on per-capita income. Electricity consumption reduces CO_2 emissions. Also, urbanization increases CO_2 emissions, and export enhance environmental quality through the reduction of CO_2 emissions. Al-mulali and Ozturk (2015) examine the impact of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation on environmental degradation in 14 MENA countries during 1996-2012. The finding based on Pedroni cointegration test shows that; variables have long-run relationship. Furthermore, the fully modified ordinary least square (FMOLS) result shows that, energy consumption, urbanization, trade openness and industrial development reduces environmental quality, while political stability increase environmental quality in the long-run. The Granger causality also shows that variables have both short and long-run causal relationship with the ecological footprint.

Chang (2015) examined the non-linear effect of financial development and income on energy consumption across 53 countries during 1999-2008. A panel threshold analysis is employed and the finding reveal that; when the private credit, domestic credit, value of traded stocks, and stock market turnover are used as indicators of financial development, they have single threshold effect on energy consumption. When the sample are divided according to income level, the result shows that the consumption of energy is moving together with increase in income in emerging market and developing countries. However, in developed economies energy consumption increase with income up to a given threshold level of income. Moreover, in low-income economies, energy consumption enhances financial development when private and domestic credits are used as a proxy of financial development. While, when the traded stocks and stock market turnover are the indicators of financial market development, it marginally reduces with the advancement of financial market in developed countries. Jebli et al. (2016) used 25 OECD countries during 1980-2010 and investigates the causal nexus between per-capita CO_2 emissions, gross domestic product, renewable and non-renewable energy consumption, and international trade. The short-run Granger causality reveal bi-directional causality between renewable energy consumption and imports, renewable and non-renewable energy consumption, non-renewable energy and trade; uni-directional causality also exist running from exports to renewable energy, trade to CO_2 emissions, output to renewable energy. All variables also shows long-run bi-directional causality among the variables. The long-run FMOLS and dynamic OLS confirmed the presence of environmental Kuznets curve (EKC) hypothesis across the sample countries. The finding also shows that; increase in non-renewable energy positively promotes CO_2 emissions, and increase in trade or renewable energy lessens CO_2 emissions.

3. ECONOMETRIC MODELS AND METHODOLOGY

One of the acceptable theory that relate environment with income is the famous EKC[1] hypothesis. This theory suggest that, in the early stage of economic development, environmental degradation and pollution keep rising. When the economy reach a certain threshold of per-capita income level, it then reverses and from there an increase in the level of per-capita income lead to an increase in environmental quality. Therefore, increase in the level of income will lead to the reduction of environmental degradation (Stern, 2004). Hence, increase in income level is a prerequisite condition for improving environmental quality as hypothesized by the EKC theory. Based on Pesaran and Smith (1995), and Pesaran et al., (1999) we presume that given data on time periods, t = 1, 2….,T, and groups, I = 1, 2……, N, the aim is to estimate an ARDL (p, q, q,……q) model,

1 For further elaboration on EKC hypothesis check Kaika and Zervos (2013), and Van Alstine and Neumayer (2013).

$$y_{it}=\sum_{j=1}^{p}\lambda_{ij}x_{i,t-j}y_{i,t-j}+\sum_{j=0}^{q}\delta_{ij}x_{i,t-j}+\mu_i+\varepsilon_{it} \quad (1)$$

Where x_{it} (k×1) is considered as the vector of independent variables for group i; μ_i stand for the fixed effects; the coefficients of lagged dependent variable x_{ij} are scalars; and δ_{ij} refers to k×1 coefficient vectors. T must be sufficiently large so as to estimate the groups independently. It is appropriate to work with the subsequent reparameterization of equation (1);

$$\Delta CO_{2it}=f_iCO_{2i,t-1}+\beta_ix_{it}+\sum_{j=1}^{p-1}\lambda_i{*}_j\Delta CO_{2i,t-j}+\sum_{j=0}^{q-1}\delta_i{*}_{t-j}\Delta x_{i,t-j}+\mu_i+\varepsilon_{it} \quad (2)$$

I = 1, 2,……, N, and t = 1, 2,…….T, where $\phi_i=-(1-\sum_{j=1}^{p}\lambda_{ij})$, $\beta_i=\sum_{j=0}^{p}\delta_{ij}x_{i*j}=\sum_{m=j+1}^{p}\lambda_{im}, j=1,2,......,p-1$ and

$$\delta_{i*j}=-\sum_{m=j+1}^{q}\delta_{im}\, j=1,2,..........,q-1 \quad (3)$$

Stacking the time series of each observation, equation (2) can be written as;

$$\Delta CO_{2i}=f_iCO_{2i,-1}+x_i\beta_i+\sum_{j=1}^{p-1}\lambda_i{*}_j\Delta x_{i,-j}\delta_i{*}_{-j}+\mu_i l+\varepsilon_i \quad (4)$$

I = 1, 2,….N, where $y_i = (y_{il},……….\ y_{iT})$ refers to T×1 vector of observations on the dependent variable of i^{th} group, $x_i = (x_{il},……….\ x_{iT})$ is T×k matrix of the observations on the independent variables that vary both for the group and time periods, i = (1,….,1) refers to T×1 vector of 1s, y_{i-j} and x_{i-j} are j lagged values of y_i and x_i, $\Delta y_i = (y_i-y_{i-1})$, $\Delta y_i = (y_i-y_{i-1})$, $\Delta x_i = (x_i-x_{i-1})$ Δy_{i-j} and Δx_{i-j} are j period lagged values of Δy_i and Δx_i, and ε_i $(\varepsilon_{il},…\ \varepsilon_{iT})$.

The coefficients of the group specific short run and long run are calculated by the pooled maximum likelihood estimation. The estimators are signified by;

$$\hat{f}_{PMG}=\frac{\sum_{i=1}^{N}\tilde{f}_i}{N},\hat{\beta}_{PMG}=\frac{\sum_{i=1}^{N}\tilde{\beta}_i}{N},\tilde{\lambda}J_{PMG}=\frac{\sum_{i=1}^{N}\tilde{\lambda}_{ij}}{N},j=1,\ldots,p\text{-}1\hat{\lambda}j_{PMG}$$
$$=\frac{\sum_{i=1}^{N}\delta_{ij}}{N},j=0\ldots,q\text{-}1,\hat{\theta}_{PMG}=\approx\theta$$

However, the MG estimator suggested by Pesaran and Smith (1995) allows the heterogeneity of all parameters and the below estimates of short run and long run parameters:

$$\hat{f}_{MG}=\frac{\sum_{i=1}^{N}\tilde{f}_i}{N},\hat{\beta}_{MG}=\frac{\sum_{i=1}^{N}\tilde{\beta}_i}{N},\hat{\lambda}j_{MG}=\frac{\sum_{i=1}^{N}\lambda_{ij}}{N},j=1\ldots,p\text{-}1\hat{\delta}j_{MG}$$
$$=\frac{\sum_{i=1}^{N}\hat{\delta}_{ij}}{N},j=0\ldots,q\text{-}1,\hat{\theta}_{MG}=\frac{1}{N}\sum_{i=1}^{N}\text{-}(\hat{\beta}_i/f_i)$$

Where ϕ_i, β_i, λ_{ij} and $\hat{\gamma}_{ij}$ are the OLS estimators got independently from equation (2). Moreover, MG technique involves estimating single regression for each sample unit and calculating averages of each sample specific coefficients. MG estimators may perhaps be not efficient if the sample size is small, because every sample outlier can strictly upset the averages coefficients of the sample. However, the long-run mean coefficients of MG estimator considers consistent and efficient, it will be inefficient if the slope is similar. The pooled estimators are reliable and effective under the long-run slope homogeneity. Homogeneity hypothesis of the long-run policy parameters cannot assumed probable outcome and is tested empirically in general specifications. The Hausman-type test (Hausman, 1978) is applied to identify the presence of heterogeneity in the means of the coefficients; the test is used to distinguish between MG and PMG. Based on the null hypothesis, the variation in the MG and PMG estimated coefficient is insignificant and PMG is regarded more efficient. The empirical model of this study is specified below;

$$CO_{2it}=\alpha_{0i}+\alpha_1INEQ_{it}+\alpha_2TO_{it}+\alpha_3GDPC_{it}+\alpha_4UB_{it}+\varepsilon_{it} \quad (5)$$

Logging the variables, we obtained equation (6) below;

$$\ln CO_{2it}=\alpha_{0i}+\alpha_1\ln INEQ_{it}+\alpha_2\ln TO_{it}+\alpha_3\ln GDPC_{it}+\alpha_4\ln UB_{it}+\varepsilon_{it} \quad (6)$$

The restricted version to estimate PMG based on 18 African countries for the period of 1984-2001 is specified below;

$$\Delta\ln CO_{2it}=(\ln CO_{2it-1}-\theta_1\ln INEQ_{it}-\theta_2\ln TO_{it}+\theta_3\ln GDPC_{it}$$
$$+\theta_4\ln UB_{it}-\alpha_{4it}-\theta_{0i})+b_{1i}\Delta\ln INEQ_{it}+b_{2i}\Delta\ln TO_{it}$$
$$+b_{3i}\Delta\ln GDPC_{it}+b_{4i}\Delta\ln UB_{it}+\varepsilon_{it} \quad (7)$$

Where; $\ln CO_2$ is the log of carbon dioxide emissions, lnINEQ is the log of income inequality, ln, To refers to the log of trade openness, lnGDPC is the log of per-capita GDP, lnUB is the log of urbanization, and ε_{it} is the unobservable error term, i indicate country, and t means time. All the variables are converted to natural logarithm for the purpose of normalization.

4. DATA

In this study, we used different data sources depending on the variable. Carbon dioxide emissions is measured by carbon dioxide emissions metric tons per-capita and is obtained from world development indicators (WDI), World Bank. Income inequality is obtained from Standardized World Income Inequality Database (SWIID). The data is obtained from Frederick (2014), the SWIID Working paper SWIID Version 5.0 October, 2014. SWIID used different inequality data bases and sources like; UN University's World Income Inequality Database version 2.0c, the OECD Income Distribution Database, the Socio-Economic Database for Latin America and the Caribbean generated by CEDLAS and the World Bank, etc. From this they come up with the comprehensive inequality indicators for various countries in the world. Trade openness is measured by aggregate import and export as a ratio of GDPC, GDP, and urbanization is measured by urban population as a percentage of the total population, and are all obtained from WDI, World Bank.

5. EMPIRICAL RESULTS

The descriptive statistics in Table 2 exhibit the number of observations, standard deviation, mean, minimum, maximum and

Table 2: Descriptive statistics

Variables	Observation	Mean	Standard deviation	Minimum	Maximum	Unit of measurements
CO_2 emissions	319	1.064	2.089	0.044	10.357	CO_2 emissions metric tons per-capita
Income inequality	301	46.561	7.662	29.244	64.703	Different inequality indicators
Trade openness	319	61.545	24.951	18.814	140.697	Aggregate exports and imports as a ratio of GDP
GDPC	319	1127.733	1239.735	136.654	5450.428	Real per-capita GDP
Urbanization	319	35.899	13.901	4.988	63.818	Urban population as a ratio of overall population

GDP: Gross domestic product

unit of measurements of the variables. The table shows that, the number of observation for CO_2 emissions, trade openness, GDPC, and urbanization is 319, while that of income inequality is 301. The mean distributions of the CO_2 emissions, income inequality, trade openness, GDPC, and urbanization are 1.064, 46.561, 61.545, 1127.733, and 35.899 respectively. Moreover, the values for standard deviation of CO_2 emissions and income inequality are 2.089 and 7.662 respectively, and also same is highlighted for the minimum and maximum values for all the variables under investigation.

Table 3 highlights the correlation matrix of the variables which shows how the variables are linked with the dependent variable. For example, with the exception of trade openness all the three variables (inequality, GDPC, and urbanization) are positively correlated with CO_2 emissions.

The main empirical result is reported in Table 4, based on three distinct models of DFE, Mean group (MG), and pooled MG (PMG) approaches. Although, the speed of adjustment of DFE shows convergence as the error correction term is negative and significant, but it shows that no any significant relationship exist between income inequality and carbon dioxide emissions in the sample countries. This phenomenon is also obtained in the short run. Moving to MG estimation technique, same result was found as that of DFE which means all the dependent variables remain insignificant on its relationship with carbon dioxide emissions. However, the result based on PMG reveals that; income inequality has a negative and significant impact on carbon dioxide emissions. This means that, 1% increase in the level of income inequality in Africa, could reduce carbon dioxide emissions by 0.052%. Therefore income inequality in Africa enhances environmental quality, because it decreases environmental degradation through reduction of carbon dioxide emissions. This research outcome contradict that of Zhang and Zhao (2014) in China, and confirmed the findings of Ravallion et al. (2000).

The outcome of other control variables shows that; trade openness, per-capita GDP, and urbanization have a positive and significant impacts on carbon dioxide emissions in Africa. This means that, 1% increases in trade openness, per-capita GDP, and urbanization could positively stimulates carbon dioxide emissions by 0.140%, 0.853%, and 0.289% respectively. These findings confirmed that of Wang et al. (2012) in China. Therefore, increase in any of these variables could trigger environmental degradation in the sample countries, because they will all increase the amount of carbon dioxide emissions. The p-value of our Hausman test as shown in the result is (0.91%), this value is greater than 5% (0.05%).

Table 3: Correlation matrix

Variables	Co_2 emissions	Income inequality	TO	GDPC	UB
CO_2 emissions	1.0000				
Inequality	0.0945	1.0000			
TO	−0.0114	−0.1641	1.0000		
GDPC	0.8623	−0.0566	0.3261	1.0000	
UB	0.4628	−0.2066	0.3778	0.6047	1.0000

CO_2 emissions: Carbon dioxide emissions, TO: Trade openness, GDPC: Gross domestic product Per-capita, UB: Urbanization

Hence, based on the econometric theory we cannot reject null hypothesis which means PMG estimator is more appropriate technique to apply. Therefore, our main focus is on PMG as the most preferred method based on the Hausman test P-value. The error correction adjustment is in tandem with econometric theory. It confirmed a convergence to long-run, because the value of the error correction term is negative, significant, and <1. This means, whenever a variable deviated from the equilibrium, it takes about 0.65% to adjust to equilibrium annually.

Environmental safety, efficiency, and improvements are among the most critical policy issues that faced developed, emerging and developing countries in the global economy. The issue of income distribution is also critical to all the countries, this is related to the fact that, very few individuals and firms control bulk of the world's resources and left majority of the populace with little share. This is being considered as a tradeoff, but the finding of this study clear the air on African countries that income variation reduces the level of carbon dioxide emissions in the countries studied. Hence the level of income could not be a determinant factor to consider when designing policies to curb environmental problems in Africa. The policy makers should therefore consider other variables like trade openness, per-capita GDP, and urbanization that trigger carbon dioxide emissions and reduces environmental quality when initiating policies to curb environmental degradation in Africa.

6. CONCLUSION AND POLICY RECOMMENDATIONS

This article applied panel ARDL techniques of MG and PMG during 1984-2001, and examine the impact of income inequality on carbon dioxide emissions among 18 selected African countries. PMG is considered more appropriate model due to the fact that we cannot reject Hausman test P-value, which is above 5% level of significance. The main empirical finding suggest that; income inequality reduces carbon dioxide emissions in Africa. That is to say, the wider the income variation, the lower the level of

Table 4: DFE, MG and PMG estimation results dependent variable: Log of carbon dioxide emissions (18 countries, 1984-2001)

Variables	DFE	MG	PMG
lnIneq	−0.312 (0.362)	−3.484 (3.143)	−0.052 (0.029)*
lnTO	0.218 (0.161)	0.187 (0.330)	0.140 (0.035)***
lnGDPC	0.824 (0.229)	−0.262 (1.230)	0.853 (0.070)***
lnUB	0.036 (0.257)	3.170 (4.363)	0.289 (0.120)**
Error correction adjustment	−0.423 (0.052)***	−1.311 (0.290)***	−0.654 (0.191)***
ΔlnIneq	−0.071 (0.376)	40.023 (39.728)	3.586 (2.517)
ΔlnTO	0.612 (0.079)	0.113 (0.226)	0.122 (0.137)
ΔlnGDPC	0.319 (0.212)	0.447 (0.467)	0.596 (0.311)*
ΔlnUB	0.747 (0.846)	34.343 (16.482)	15.687 (8.512)*
Maximum log likelihood	-	-	360.769
Number of parameters	4	4	4
Hausman test	-	0.99 (0.912)	0.99 (0.912)

DFE: Dynamic fixed effect, MG: Mean group, PMG: Pooled mean group, GDP: Gross domestic product. We included Country specific term in the equations, figures in parentheses shows t-statistics while P values is used for Hausman test which indicated the level of significance at ***1%, **5% and *10% levels respectively

environmental degradation in Africa. The finding based on other control variables reveals that; the impacts of trade openness, per-capita GDP, and urbanization are positive and statistically significant on carbon dioxide emissions. Therefore, an increase in any of the aforementioned variables could positively and significantly accelerates carbon dioxide emissions in Africa. Hence, while the disparity in income between different segments reduces carbon dioxide emissions, conversely increase in trade openness, per-capita GDP, and urbanization stimulates it Africa. The recommendations remain that; policy makers in Africa should not consider income distribution important while formulating policies concerning environmental quality. This is because income inequality does not deteriorate environmental quality, rather it improves it through the reduction of carbon dioxide emissions.

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APPENDIX

Appendix Table 1: Sample courtiers of the study

Cameroon
Cape Verde
Cote d`Ivoire
Egypt
Ghana
Kenya
Madagascar
Malawi
Mali
Mauritania
Mauritius
Morocco
Nigeria
Rwanda
Sierra Leone
South Africa
Tunisia
Zambia